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AN ANNOTATED BIBLIOGRAPHY OF ABSTRACTS ON THE USE OF SIMULATORS IN TECHNICAL TRAINING

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This document contains annotated abstracts of 149 selected papers from the literature on simulator training devices and programs. The abstracts are organized into two sections: abstracts of 83 empirical articles and abstracts of 66 theoretical articles. For ease of reference and retrieval, each abstract is organized according to a standardized 9-point format, with the following headings: (1) Authors; (2) Title; (3) Source; (4) Topic Keywords; (5) Short Summary; (6) Device; (7) Institution; (8) Type of Article; (9) Abstract. The purpose of these annotated abstracts is to (Continued)

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20. (Continued)

effectively summarize, and not merely to describe or identify, the contents of the papers under review. The abstract will be entered into a computerized data base for future analyses.

U. S. ARMY RESEARCH INSTITUTE
FOR THE BEHAVIORAL AND SOCIAL SCIENCES

A Field Operating Agency under the Jurisdiction of the Deputy Chief of Staff for Personnel

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Research Product 84-21

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Training and Simulation

FOREWORD

The Training and Simulation Technical Area of the Army Research Institute for the Behavioral and Social Sciences (ARI) performs research and development in areas that include training simulation with applicability to military training. Of special interest is research in the area of training device design requirements. The Army requires guidance in the design of training devices and training systems if it is to provide the most effective training at the lowest costs.

This research product is a collection of annotated abstracts which may serve two major purposes. They may serve as a comprehensive introduction to the literature on training device application and evaluation and they may also serve as the beginning of a computerized data base for training device and training system information. Such a data base must be developed before future efforts to develop decision support systems for training design guidance may be productive.

Training device and training system design guidance will facilitate the efforts of training device procurers such as the Army Project Manager for Training Devices (PM TRADE) and also instructional systems developers in the Army Training and Doctrine Command (TRADOC).

Edgar M. Johnson

EDGAR M. JOHNSON
Technical Director

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ACKNOWLEDGMENTS

The authors wish to thank the following individuals whose efforts greatly facilitated the accumulation and publication of these annotated abstracts. Vernessa Clark, Cheri Wiggs, and Vanessa Irizarry provided substantial editorial and clerical assistance in the preparation of this document. Ray Perez, Douglas Dressel, and Stan Bolin conducted technical reviews of the document and provided many useful suggestions concerning the organization of the abstracts. They also conducted validity assessments of the abstracts. Finally, we wish to thank John Allen, who served as project director in the early phases of this effort and without whose help these abstracts could not have been compiled.

AN ANNOTATED BIBLIOGRAPHY OF ABSTRACTS ON THE USE OF SIMULATORS IN TECHNICAL TRAINING

EXECUTIVE SUMMARY

Requirements:

To compile a comprehensive annotated bibliography on the use of simulators in technical training and provide a reference and resource for researchers, expert system data base developers, training program administrators, and simulator decision-makers by (1) designing standardized formats for effectively summarizing the most important and useful information contained within technical reports and other research documents, and (2) writing annotated abstracts, implementing this format, of selected documents from the simulator training literature.

Procedure:

This document primarily consists of 149 annotated abstracts of selected research papers from the literature on simulator training. The abstracts are arranged alphabetically by first author's name within two broad groupings: theoretical and empirical. Each abstract is organized according to the same 9-point format, under the following headings: (1) Authors; (2) Title; (3) Source; (4) Topic Keywords; (5) Short summary; (6) Devices discussed or studied; (7) Institution; (8) Type of Article; and (9) Abstract. These 9 headings are further broken down into subheadings and filled in with appropriate information, if available in the original document.

Findings:

The simulator literature is characterized by considerable diversity--in terms of purpose, method, and theoretical framework--as well as variability--in terms of quality and validity. Due to small sample sizes, the absence of controls, or the narrow range of treatments, many of the studies in the simulator literature would be considered flawed by academic standards. More effort needs to be devoted to critically evaluating and consolidating the results of past research in this field. In order to make practical use of the diverse findings of the hundreds of researchers who have contributed to the simulator training literature, it is desirable that these findings be summarized and organized into a single data base, to allow for critical comparison, cross-referencing, and ultimately, assimilation into an expert system for training design guidance. The completion of these annotated abstracts, organized by a

standardized 9-point system, represents a step toward the goal of unifying the simulator literature and putting its findings to practical use.

Utilization of Findings:

These annotated abstracts may be used by those interested in or responsible for research on simulator training. This document may serve as a reference guide, enabling the investigator to gain immediate access to a pertinent segment of the simulator training literature. The document may also be useful to those responsible for planning future research on training system issues. The abstracts themselves can be entered into a computerized data base and information may be accessed from any of the 9-point categories according to a simple coding scheme. The information contained in these abstracts may therefore be helpful to those involved in the development of decision support systems for training device design guidance.

AN ANNOTATED BIBLIOGRAPHY OF ABSTRACTS ON THE USE OF SIMULATORS IN TECHNICAL TRAINING

CONTENTS

I. INTRODUCTION

Those responsible for designing training devices and programs need a basis upon which to decide what level of simulator fidelity will produce the optimal training effect for the cost. A logical basis for making simulator fidelity decisions is the empirical findings of researchers who have systematically studied the relationship between simulator fidelity and training effectiveness. Since there is already a substantial body of research literature in existence that bears on simulator fidelity, it makes sense to try to pull this literature together to organize it, summarize it, and make it available to decision-makers and others who are working in the simulator field. An annotated bibliography can help accomplish this.

However, the abstracts contained in most annotated bibliographies are too brief and superficial to be very helpful. Ideally, an abstract should summarize the contents of a document, and not merely describe or identify those contents. Previous abstract writers have tended to avoid details altogether, rather than face the difficult task of selecting only the most essential details from a given document. An attempt has been made here to not only summarize a document in general terms, but also to extract from each document the most significant details contained within it, including the key empirical findings from the experimental studies. It is hoped that this will help provide a basis for comparing, analyzing, and critically evaluating the results of different studies of different devices at different levels of fidelity that have been conducted over the years. The publication of these abstracts will be a step toward the establishment of a master data base containing the empirical results of all major studies bearing on simulator fidelity.

This document is the first iteration in a long process designed to accumulate, organize, summarize and make available the empirical and theoretical information the U.S. Army needs to make training decisions. The format may change as new methods are found for organizing and summarizing the research literature. In addition reliability checks are continuing. While every effort has been made to ensure consistency and accurateness in the annotation process, the short summaries and the abstract summaries, are somewhat subjective. When greater clarity or detail is required the original source citation is available in the reference section.

II SOURCES, ORGANIZATION, AND PURPOSE OF THE ABSTRACTS

The literature from which these annotated abstracts were written was gleaned, for the most part, from online searches of the following databases: Psychological Abstracts, NTIS, ERIC, GPOM and STAR. The abstracts are arranged alphabetically according to the name of the first author within two main categories: theoretical and review articles and articles reporting empirical studies. The abstracts cover a period of time from 1957 until 1982. The articles which have been abstracted in this document were purposely restricted to those that directly relate to simulation based training devices. This narrow scope was chosen because resource constraints limited the total number of articles that could be abstracted. Furthermore, by limiting the types of articles abstracted, it was felt that a more thorough job could be done on the articles chosen.

Many of the articles abstracted here are military technical reports, published by such agencies as the Air Force Human Resources Laboratory, the Naval Training Device Center, and The U.S. Army Research Institute. Copies of these documents can usually be ordered from the National Technical Information Service (NTIS) in Springfield, Virginia.

This document contains abstracts of 149 articles. The articles have been organized into two main categories: empirical and theoretical. The abstracts of 83 empirical articles are presented first and organized alphabetically by first author or sponsoring organization, if no authors are cited. Within the category of empirical articles, five subcategories are detailed: (1) experiments - studies which manipulate variables, (2) surveys - studies which systematically accumulate data from relevant sources with interviews or questionnaires, (3) case studies - in depth investigations of single instances, (4) analytical - systematic application of an analysis methodology without the manipulation of variables, and (5) meta-analyses - statistical compilations of experimental results on specific variables and relationships across several studies. The abstracts of 66 theoretical articles, also organized alphabetically by first author or sponsoring organization, are presented next. Within the category of theoretical articles, four subcategories are detailed: (1) theoretical - a rigorous logical approach to issues, (2) review - a summary of some portion of the research literature, (3) conceptual - opinions, statements of "important" issues, etc., and (4) methodological - plans, approaches, and research guidelines. Finally, a reference list of all the articles abstracted is presented. This reference list contains the page number of the corresponding abstract.

c. Tests or Trials/Timing: 2 post-tests

d. Number of Different Types of Measures: 1

e. Description of Measurements and Ratings: Lateral deviation of wheel rim from true (mean peak)

f. Experimental Setting/Training Context: Laboratory experimental, hands-on (where device functional)

g. Statistical Methods: t-test, one-way repeated measures ANOVA; two-way repeated measures ANOVA; Pearson correlations.

h. Variables Being Manipulated:
(1) Training Devices: as above, section 6
(2) Fidelity Levels:

	Physical	Functional
Actual equipment working	High	High
Computer graphics	Low	High
Degraded model of actual equipment	Medium	Medium
Actual equipment not working	High	Low
Line drawings	Low	Low

(3) Type of Task/Skill Required: truing bicycle wheel; psychomotor; motor; perceptual.
(4) Task Difficulty: Medium-low

i. Stage of Training: introduction; familiarization; skill

j. Trainee Sophistication: novice

k. Incorporation of Device into P.O.I.: not applicable

l. User Acceptance or Attitude: not discussed

m. Use of Instructional Features:
(1) Intensity: minimal to incomplete (for computer-graphics device)
(2) Features used: not specified

9. Abstract:

a. Study Synopsis: This paper described the experimental implementation of a design formulated in an earlier part of this study (Baum, et. al.,

1. Authors: Baum, David R., Riedel, Sharon, Hays, Robert T., & Mirabella, Angelo

2. Title: Training Effectiveness as a Function of Training Device Fidelity.

3. Source: Simtrain Task 2 Final Report, August 1982.

4. Topic Keywords: Fidelity ; Physical Fidelity ; Functional Fidelity ; Fidelity Specifications ; Maintenance Training Simulation ; Perceptual-Motor tasks .

5. Short Summary: This experiment examined the effects of varying training device fidelity on training effectiveness in a perceptual-motor task. The experiment found that significant and meaningful effects occur in relation to the physical dimension of fidelity (device appearance), but not in relation to functional fidelity (device operability and response). The experiment had problems in the experimental methodology, however.

6. Devices: Bicycle-wheel truing devices

a. Actual Equipment in working order

b. Computer graphics display of equipment

c. Degraded 3-dimensional model of equipment

d. Actual equipment but not working (none of parts moved)

e. Line drawings of equipment

7. Institutions:

a. Sponsor: U.S. Army Research Institute for the Behavioral and Social Sciences (PERI-IC), 5001 Eisenhower Avenue, Alexandria, VA 22333.

b. Performing Organization: Honeywell Systems and Research Center, 2600 Ridgway Parkway, P.O. Box 312, Minneapolis, MN 55440.

8. Type of Article: Experiment.

a. Number of Groups: 5

b. Description of Groups: (1)-(5) Subjects: (Each group) 17 male and 3 female, 3 of whom were technical school students, mean age approximately 17, non-college-bound.

Under forward chaining, poor performance often results in the termination of the student prior to completing the task. In the case of a weapons delivery task such as this, the student under the backward chaining method has the opportunity to drop more bombs per unit of training time than would a student under the whole task method or a forward chaining method. Given that bomb-dropping is the essence of this particular task, backward chaining allows more actual practice time than does either the whole task method or forward chaining.

different in initial skill on the task. All training and testing were done in the Advanced Simulator for Pilot Training.

The backward-chaining group learned the bombing tasks as four sub-tasks in the following order: (1) Final; (2) Roll-in; (3) Base Leg; (4) Down-Wind. After learning each sub-task to criterion, they "graduated" to learning the task which was previous to it in real-life terms. After learning all the sub-tasks to criterion, they performed five trials of the whole task, with all maneuvers in their proper sequence. These last five trials constituted their post-test.

The whole-task group performed 30 trials of the whole task, in which no segment was distinguished for them as a "test". Their performance of trials 15-19 were subsequently selected as the post-test to be compared with the backward chaining group. The reason given was that by trial 14 this group had received training time equal to what the backward-chained group had received by the criterion method.

b. Results:
  (1) Key Data:
    (a) Mean Circular Error (over 5 trials):
    Backward Chaining Group : 134.38 feet
    Whole Task Group: 182.34 feet
    (b) Percent Reaching Criterion in equal time:
    Backward Chaining Group: 70%
    Whole task group: 30%
  (2) Verbal Description of Results:
  Backward-chained subjects showed significantly greater accuracy in the task after equal training time. (Chi Square = 5.0, df=1, $p<.05$). Not only was the accuracy of the subjects in the backward chaining condition superior when training time for the two groups was equated, but the rate at which students reached criterion was significantly faster under the backward chaining condition.

c. Authors' Conclusions: The results of the present study indicate a clear, systematic reduction in circular error with the use of a backward chaining method for introducing the 30 degree dive bomb task. However, the present study does not address the potential effectiveness of forward chaining as an alternative to the whole task approach. Both chaining methods offer some advantages over traditional whole task methods.

hands-on

g. Statistical Methods: groups mean, group percentages

h. Variables being manipulated:
(1) Training Device: Advanced Simulator for Pilot Training, G-seat inflated but not operating, platform motion not operating
(2) Estimated Fidelity Levels:
(a) Physical: high
(b) Functional: high
(3) Type of Task/Skill Required: operations, cognitive, psychomotor, part-task, whole-task
(4) Task Difficulty: high

i. Stage of training: skill, familiarization/introduction new task

j. Trainee sophistication: generally high/intermediate/expert

k. Incorporation of device into P.O.I.: not applicable

l. User acceptance or attitude: not discussed

m. Use of Instructional Features:
(1) Intensity: not specified, presumed intensive
(2) Features used: not specified

9. Abstract:

a. Study Synopsis: Training by "backwards chaining" involves separating the task to be learned into steps, which are then learned in reverse order of their real-lifetime sequence. Behavioral principles indicate that this technique should be superior to the whole-task, continuous, beginning-to-end training method for many types of tasks. In this study, the backwards chaining method was applied in teaching a simulated dive-bombing task to experienced pilots. Their training time to criterion in the task, and their accuracy in test runs of the whole task, as measured by circular error (distance of simulated bomb impact from target) were compared with the performances of an equivalent group trained by the whole-task method.

The subjects were two groups totalling 20 Air Force Instructor pilots who were familiar with the simulated aircraft but not with the task to be learned. By pre-test the groups were found not to be significantly

1. Authors: Bailey, John, Hughes, Ronald, & Jones, William

2. Title: Application of backward chaining to air-to-surface weapons delivery training.

3. Source: Air Force Human Resources Laboratory Technical Report (AFHRL-TR-79-63), April 1980.

4. Topic Keywords: Flight Training ; Backward Chaining ; Whole-task ; High Fidelity Simulator ; Response Chaining ; Weapons Delivery ; Air-to-ground attack .

5. Short Summary: Two groups of student pilots were trained on a dive-bombing task, one group by the whole-task method, and the other by a backward-chaining method. Both groups were trained on the simulation equipment. The backward-chaining group reached criterion with fewer trials, and were more accurate given an equal number of trials.

6. Device: Advanced Simulator for Pilot Training, high-fidelity visual and instrument flight simulator

7. Institutions:

a. Sponsor: AFHRL HQ Air Force Human Resources Laboratory (AFSC), Brooks AFB, TX 78235.

b. Performing organization: Flying Training Division, AFHRL, Williams AFB, AZ 85224.

8. Type of Article: Experiment.

a. Number of Groups: 2

b. Description of Groups:
(1) Subjects in Backward Chaining Group: approximately 10 Air Force Instructor pilots
(2) Subjects in Whole-task Group: same

c. Tests or Trials:
(1) For Backward Chaining Group: one post-test (5 trials)
(2) For Whole-task Group: 5 in-process trials
(3) For Both Groups: pretest to establish baseline

d. Number of Different Types of Measures Used: 1

e. Description of Measures/Ratings: Mean circular error (distance of simulated bomb impact from target)

f. Experimental Setting/Training Context: Laboratory,

Empirical Articles

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*Note: Many of the above categories require estimates or subjective judgments on the part of the reviewer. Some errors and inaccuracies are inevitable. All such errors and inaccuracies are regrettable and every reasonable effort has been made to avoid them.

IV EXPLANATION OF THE ABSTRACT FORMAT FOR THEORETICAL ARTICLES

Each of the annotated abstracts of theoretical articles is organized under the following 9-point format:

1. Author(s): The author(s) of the document, starting with the last name of the first author; if the authors are not identified, the performing organization is identified in the author's place.

2. Title: The title of the document, including subtitles.

3. Source: The publication source of the document, including, if available, the identifying code numbers of the sponsoring agency's catalog system.

4. Topic Keywords: Keywords, such as those appearing as topic headings in major relevant reference book indexes--e.g. "Training Device Effectiveness" or "Flight Simulation"--which identify the specific subject matter of the document.

5. Short Summary: A short summary of the contents of the document for quick feference or review.

6. Device(s): The devices discussed in the article.

7. Institutions

    a. Sponsor: The agency which sponsored, contracted, funded, directed, or arranged for the effort.

    b. Performing Organization: The agency which conducted the effort, which employed the authors of the article, or with which the authors of the atricle were affiliated.

8. Type of Article: (e.g. Review, conceptual, theoretical, methodological)

9. Abstract: This section contains a verbal summary of the document with the authors' conclusions.

(2) Features Used: A list of instructional features of the device, as specified by the authors, that are actually used in the training program under study--e.g. freeze capability, restart/resequence capability, sign-in capability, augmented feedback, record/playback, adaptive syllabus, etc.

9. Abstract: This section contains the verbal summary of the document as well as the summary statistics.

a. Study Synopsis: A verbal summary of the study, its purpose, hypotheses, methods, procedures, subjects, controls, etc.

b. Results: Here is where the most significant or representative empirical data extracted from the document are presented.

(1) Key Data: The most significant or representative statistics are presented in tabular form, whenever possible.

(2) Verbal Description: A discussion of the key data and their implications.

c. Authors' Conclusions: The authors' interpretations of their findings and conclusions.

* Note: Many of the above categories require estimates of subjective judgments on the part of the author of the abstract. Some errors and inaccuracies are inevitable. All such errors and inaccuracies are regrettable and every reasonable effort has been made to avoid them.

(3) Type of Task/Skill Required: Classification of the type of behavioral skills required in performance of the task being trained--e.g. operations, cognitive, psychomotor, perceptual, procedural, etc.
(4) Task Difficulty: Classification of the level of difficulty of the task being trained--i.e. low/medium/high.

i. Stage of Training: The stage of training at which the simulator is used in the training program--e.g. nomenclature, familiarization, procedural, skill, transition, refresher, proficiency testing, etc.

j. Trainee Sophistication: The level of sophistication of the trainees in the study--i.e. novice, intermediate, advanced, expert, graduates of the program, 2 years on the job, etc.

k. Incorporation of Device into Program of Instruction: The instructional method by which the training device is employed when it is incorporated into a training program--e.g. self-paced, lock-step, instructor-managed, etc.

l. User Acceptance or Attitude: Attitudinal factors can have an impact on training device effectiveness. If the authors provide any indication of the attitude of either instructors or students, it will be included here.
(1) Instructors: Indications of the attitude of the instructors toward the training device, derived from questionnaires, interviews, etc.
(2) Students: Indications of the attitude of the students toward the training device, derived from questionnaires, interviews, etc.

m. Use of Instructional Features: The utilization of special instructional features is one potential advantage of simulators over actual equipment, and may, in some cases, compensate for lower fidelity. The presence and potential impact of such features are noted here.
(1) Intensity: An estimate of the degree to which instructional features are used in the training program and might conceivably affect the effectiveness of the device--e.g. minimal, incomplete, intensive, etc.

(1) Subjects: The number of experimental subjects and their key demographic characteristics as described by the authors--e.g. age, sex, level of experience, etc.

(2) Controls: The number of control subjects and their key demographic characteristics as described by the authors--e.g. age, sex, level of experience, etc.

c. Tests or Trials/Timing: an explanation of the timing and sequence of the tests or trials in relation to the treatment--e.g. pretest, in-process trial, post-test, etc.

d. Number of Different Types of Measures: The number of types of measures or dependent variables reported by the authors and/or taken into consideration in reaching the study's conclusions.

e. Description of Measurements and Ratings: A description of each type of measure, rating, or dependent variable reported in the study--e.g. number of errors, time-to-completion, instructor ratings, etc.

f. Experimental Setting/Training Context: Identification of the setting or context of the study: e.g. institutional, classroom, hands-on, field, on-the-job training, etc.

g. Statistical Methods: The statistical method(s) specified by the authors; if the authors do not specify what statistical method they employed, this will be indicated.

h. Variables Being Manipulated: The independent variables of the study.

(1) Training Device(s): Training devices that are being tested, compared, or manipulated in the study.

(2) Fidelity Level(s): Estimated fidelity level of experimental device--e.g. low/medium/high.

(a) Physical: Estimated level of physical fidelity of the experimental device--e.g. low/medium/high.

(b) Functional: Estimated level of functional fidelity of the experimental device--e.g low/medium/high.

III. AN EXPLANATION OF THE ABSTRACT FORMAT FOR EMPIRICAL ARTICLF~

Each of the annotated abstracts of empirical articles is organized under the following 9-point format:

1. Author(s): The author(s) of the document, starting with the last name of the first author; if the authors are not identified, the performing organization is identified in the author's place.

2. Title: The title of the document, including subtitles.

3. Source: The publication source of the document, including, if available, the identifying code numbers of the sponsoring agency's catalog system.

4. Topic Keywords: Keywords, such as those appearing as topic headings in major relevant reference book indexes--e.g. "Training Device Effectiveness" or "Flight Simulation"--which identify the specific subject matter of the document.

5. Short Summary: A SHORT summary of the contents of the document for quick reference or review.

6. Device(s): The training device(s) being tested, compared, manipulated, or otherwise employed in the study for experimental or evaluative purposes.

7. Institutions

   a. Sponsor: The agency which sponsors, contracts, funds, directs, or arranges for the study.

   b. Performing Organization: The agency which conducted the study, which employs the authors of the study, or with which the authors of the study are affiliated.

8. Type of Article: (experiment, survey, case study, meta analytic)--where applicable the following subheadings appear:

   a. Number of Groups: The number of groups involved in the experiment.

   b. Description of Groups: A brief description of subjects and controls.

The accumulation of these annotated abstracts serves two major purposes. First, the abstracts, as they now stand, can be entered into the literature on training device research and serve as an excellent introduction and summary for researchers new to this area. A second and possibly more important purpose for these abstracts is that they will be entered into a computerized data base for future analyses. The abstracts have been formatted to facilitate their coding for easy computerized retrieval of information. The next sections explain the format for the abstracts of the empirical and theoretical articles.

Specification of Training Simulator Fidelity: A Research Plan, 1982), whose purpose was to investigate the training effect of varying simulator fidelity in military maintenance tasks. In this study, the manipulation of simulator fidelity was applied to a perceptual-motor task of moderately low difficulty.

Following the definition of Hays described in the earlier paper, the fidelity of simulation was separated into two dimensions--"physical" and "functional"--and an experimental task was chosen in which these two dimensions could be varied independently of each other insofar as possible. The experimental design, suggested by Hays (1981) was as follows (the five blocks marked are the ones investigated in this experiment):

Functional Similarity	Physical Similarity: High Actual Device	Medium 3-D Model	Low Pictures/ Graphics
High: works with effect	XX XX		XX XX
Medium: works with no effect		XX XX	
Low: Does not work	XX XX		XX XX

Results of experimentation in the five blocks would, it was expected, represent the impact of variance within the full range of fidelity in the two dimensions.

The task selected for study was the truing of a bicycle wheel. It matched the design requirements well, was easily studied and controlled in a laboratory, and was felt to be representative of Army perceptual-motor maintenance tasks in general.

Subjects were chosen as being representative of the Army volunteer population. There were 100 non-college-bound men and women with a mean age of 17.25 years. They were randomly assigned to five conditions, groups of 20 each, with the following constraints: each condition had 17 males, 3 females and 3 technical students.

The five experimental devices were, in brief: (1) Actual equipment in working order -- high physical, high functional fidelity; (2) computer graphics display of equipment -- low physical, high functional fidelity; (3) degraded 3-dimensional model of equipment, parts moved but produced no effect -- medium physical, medium functional fidelity; (4) actual equipment but no parts working -- medium physical, low functional fidelity; and (5) line drawings of equipment -- low physical, low functional fidelity.

Subjects were trained on the five devices separately, and were subsequently given two 15-minute performance tests on the actual equipment (which was the High/High training device). Measurements were taken of the lateral deviation of the wheels from "true" (another component of "true", roundness, was not studied).

Proposals for future research, particularly in the cognitive area, were also made in this paper.

b. Results:

(1) Key Data:

Average of sum of peak rim deviations for Trials 1 and 2 (thousandths of an inch)

Group:	Initial Set-up	Conclusion of tests
Actual Equipment Trainer	275	85
Nonoperational Actual equipment	280	87
Computer Graphics	277	135
Line Drawings	265	140

(Reviewer's Note: The numbers above are approximations drawn from graph representations in the text. (6 measurements were actually taken for each test, at 3-minute intervals). Text did not supply data on 5th device.)

Also, a group of "experts" were tested on the device, whose greatly superior performance to subjects showed that a ceiling effect was not taking place among subjects.

(2) Verbal Description: All of the t-tests comparing the initial and final measurements of each group were statistically significant at $p < 0.005$. Any adjustment made will still yield significance levels of at least $p < .05$. These

results indicate that regardless of the training device used, subjects' mean performance improved significantly over the course of each trial.

A two-way repeated measures ANOVA revealed that the main effect of physical similarity is statistically significant, $F(1, 75) = 4.157$, p¼.05. Neither the main effect of functional similarity nor any of the interactions effects are significant.

c. Authors' Conclusions: Training on all five devices led to significant improvement during performance trials. Even subjects trained using line drawings of the equipment showed transfer of learning. All of the devices were therefore effective in training-wheel truing.

The performance of the expert group shows that the lack of a significant fidelity effect is not due to a ceiling effect--none of the other groups performed as well as the expert group.

For training of this task, effectiveness is a function of the physical similarity of the training device to the actual equipment, but is not affected by functional similarity.

Without an optimized interface and training method, the computer graphics device provides no learning facilitation for this task beyond that found with a set of line drawings.

While the general level of fidelity had no effect on training effectiveness... it was shown that physical similarity has a significant impact; functional similarity has no effect. This seeming paradox, that general fidelity does not achieve significance while one of its dimensions does, is attributable to the high variablility within each group and the increased degrees of freedom and estimation precision that comes from combining groups to assess the effects of physical and functional similarity.

Fidelity must be operationalized as consisting of at least two dimensions -- physical and functional similarity.

1. Authors: Bernstein, Bernard R. & Gonzalez, Barbara K.

2. Title: Learning, Retention and Transfer in Military Training, 1970.

3. Source: Technical Report: NAVTRADEVCEN 69-C-0253-1.

4. Topic Keywords: Imagery ; Task Difficulty ; Low Fidelity .

5. Short Summary: Three experiments address the issues of imagery and fidelity in the training of procedural tasks. These experiments validate the use of low fidelity paper and pencil simulations and suggest that imagery facilitates learning.

6. Devices:

a. Experiment Three.
(1) Communications console (the test apparatus).
(2) Preliminary training aid, cartoon slides analogous to console problems, plus text.
(3) Preliminary training aid, cartoon slides directly representing console problems, plus text.
(4) Same as (3), without text.
(5) Verbal text only.
(6) Training manual.

b. Experiment Four.
(1) Communications console (the test apparatus).
(2) Preliminary training aid, cartoon slides directly representing console problems, plus text.
(3) Training manual.

c. Experiment Five.
(1) Communications console (the test apparatus).
(2) High fidelity drawing of console.
(3) Medium fidelity drawing of console.
(4) Low fidelity drawing of console.

7. Institutions:

a. Sponsor: Naval Training Device Center, Orlando, FL

b. Performing Organization: Honeywell Inc., Systems and Research Division, St. Paul, MN 55113

8. Type of Article: Experiments.

a. Number of Groups: Experiment III, 5; Experiment IV, 3; Experiment V, 3

b. Description of Groups:

(1) Experiment III: (1)-(5), four experimental and one control group; each 8 volunteer college undergraduates, age 18-25.
(2) Experiment IV: (1)-(3), two experimental and one control group; each 10 volunteers from college introductory psychology classes.
(3) Experiment V: (1)-(3), each group 16 volunteer male undergraduate college students.

c. Tests or trials/timing: In-process trials, post-tests, delayed post-tests.

d. Number of different types of measures: 2.

e. Description of measurements and ratings:

(1) Response time to complete sub-routines.
(2) Accuracy.

f. Experimental setting/training context: Laboratory, classroom and hands-on.

g. Statistical methods: t-tests and ANOVA.

h. Variables being manipulated:

(1) Devices: as in section 6 above.
(2) Fidelity levels:

	Physical	Functional
Experiment III, all devices	Low	Low
Experiment IV, all devices	Low	Low
Experiment V, device b	Medium-Low	Low & Very Low
device c	Low	Low & Very Low
device d	Very Low	Low & Very Low

(3) Type of task/skill required: cognitive, psychomotor, procedural, part-task.
(4) Task difficulty: medium.

i. Stage of training: introduction.

j. Trainee sophistication: novice.

k. Incorporation of device into P.O.I.: lock-step (not really applicable).

l. User acceptance or attitude: not discussed.

m. Use of instructional features:
(1) Intensity: incomplete.
(2) Features used: not specified.

9. Abstract:

a. Study Synopsis: This study continued an investigation into factors affecting training effectiveness, in which two previous experiments had already been conducted; theoretical commentary on those experiments was included here. Those two experiments had generated tentative hypotheses relevant to the roles of imagery, device fidelity, and cognitive understanding in the learning of procedural tasks, and the three experiments reported here tested and expanded on those hypotheses. Another part of this study was a survey of training personnel regarding the issue of task difficulty: the results of the survey were inconclusive and are not discussed below.

b. Experiment III: The first experiment of the later phase of the overall investigation explored the use of imagery materials as aids to enhance verbal material which introduced trainees to tasks on a communications console. In preliminary training (prior to "acquisition training on the console itself, which was followed by transfer testing on the console), four groups of trainees were given aids in the form of cartoon drawings with different degrees of relevance to the tasks to be performed; one of these groups was deprived of any text; another group heard the text but was deprived of drawings; the fifth control group, was simply given a training manual to study. Measurements of performance were time to complete the task, and accuracy.

Results of Experiment III: ANOVA's were performed on the acquisition and transfer data for both response time and accuracy scores. The various conditions failed to produce a significant main effect in either session for either measure. The trial blocks effect was reliable, showing a learning effect for both time and accuracy in both training and transfer sessions.

Also, perhaps most importantly, it was discovered that the control group in the experiment performed significantly better than the control group in an earlier experiment for the same task. This could be attibuted to improvements in the instruction methods between the two experiments, and it would account for the lack of a significant difference between the experimental and control groups in this latter

experiment.

c. Experiment IV: This expanded on Experiment III by analyzing the effect of trainees' verbal aptitude, as measured by the Ammons Quick Test, on performance. An interaction was hypothesized between verbal aptitude and the impact of imagery technique on learned performance. The number of conditions was reduced from five to three (one control, two experimental).

Results of Experiment IV: Neither the verbal skill levels nor the imagery conditions produced a statistically significant main effect. The elevated performance of the control group vis-a-vis the earlier "Experiment II" control group, again appeared to account for the lack of differences between groups as an effect of imagery.

d. Experiment V: This experiment investigated the effect of six different levels of simulator fidelity. The task was the same procedural task as in Experiments III and IV. The training aids were line drawings of the console. Physical fidelity was varied by the similarity of the drawings to the console. Two levels of functional, or "response" fidelity were employed: low (written responses on the drawings, rather than instrument manipulations) and very low (verbal responses, which of course required no manual activity).

Results of Experiment V: Neither variation in physical ("stimulus") or functional ("response") fidelity produced a significant main effect.

e. Authors' Conclusions: The research accomplished has dealt with only one category of behavior. The findings for skills other than procedural may differ.

Of the variables under study, the findings associated with fidelity of simulation appear to be the most conclusive. We now have considerable evidence that relatively high levels of training effectivenes for proceduraL tasks can be maintained in the absence of high physical fidelity between training and transfer tasks. This appears to be true both in terms of the stimulus and respose components of the task ("Physical" and "Funcional" fidelity--reviewer's note). These findings lend support to Wittrock's concept of mediated generalization as the basis of transfer in procedural skills. Apparently, subjects can cope with variations in the stimulus and response components of the task as long as the basic system structure remains unchanged.

With respect to an interaction between trainee verbal skill and imagining techniques, the present investigation does not appear to provide conclusive results. The absence of predictive validity for the Ammons Quick Test may be the result of an excessively restricted range in verbal skills for the subjects used. Over half of the subjects scored at the mean for college students or within two points of the mean. It may be worthwhile to run another group of subjects who score significantly lower than the college students used in this study.

Regarding the effects of imagery in teaching procedural tasks, these experiments are inconclusive, especially as there are several factors which may influence the effectiveness of imagery, quite apart from the use of imagery per se. Among the more important are: (1) subject verbal skill, unanswered by Experiment IV, (2) nature and complexity of the task, (3) correspondence between imagery and the written or spoken text, (4) degree of explicitness of the images supplied, (5) development of associations between images and words.

1. Authors: Bickley, William R. & Bynum, James A.

2. Title: Training Device Effectiveness: Formulation and Evaluation of a Methodology.

3. Source: U.S. Army Research Institute Research Report, September 1980.

4. Topic Keywords: Training Effectiveness Ratio ; Transfer of Training ; Helicopter Flight Simulation .

5. Short Summary: A formula devised for measuring effectiveness of simulation training was tested on a helicopter flight simulator and found valid on a per maneuver basis.

6. Devices:

a. AH-1 helicopter.

b. AH1FS high fidelity flight simulator.

7. Institutions:

a. Sponsor: U. S. Army.

b. Performing Organization: U.S. Army Research Institute Field Unit, Fort Rucker, AL 36362.

8. Type of Article: Experiment.

a. Number of groups: 2.

b. Description of groups:
(1) Subjects: Approximately 21 rated Army helicopter pilots ("approximately," because data from some individuals on particular maneuvers was discarded since training on those maneuvers fell outside specifications).
(2) Controls: 14 same.

c. Tests or trials/timing: Post-tests.

d. Number of different types of measures: 1.

e. Description of measurements and ratings: Trials to criterion (criterion measured by instructor pilots on a 9-point scale, with 9 signifying criterion proficiency).

f. Experimental setting/training context: institutional, hands-on.

g. Statistical methods: regression analysis; SPSS program NONLINEAR (Robinson 1977); Marquardt's method.

h. Variables being manipulated:
(1) Training devices, as above, section 6. Chief independent variable was number of device training trials prior to aircraft training to criterion; for each maneuver, there were three different levels of training.
(2) Fidelity levels of simulator:
(a) Physical: high
(b) Functional: high
(3) Type of task/skill required: operations, cognitive, psychomotor, perceptual, part-task.
(4) Task difficulty: high

i. Stage of training: transition

j. Trainee sophistication: intermediate

k. Incorporation of device into P.O.I.: lock-step

l. User acceptance or attitude: not discussed

m. Use of instructional features:
(1) Intensity: not specified; assumed intensive
(2) Features used: Freeze capability; Restart/resequence capability; Malfunction selection; Automated demonstration; Record/playback

9. Abstract:

a. Study Synopsis: A limitation of the Cumulative Transfer Effectiveness Ratio proposed by Roscoe (1971) is its high dependence on a specific amount of simulator training. This study sought to validate a model which would calculate simlator training effectiveness for all amounts of simulator training, by applying it to the case of a simulator of heliopter flight.

The proposed formula is expressed as y = ae - bx + c, where y is the amount of aircraft training required after simulator training, a is an arbitrary constant, b is the proportional constant, and x is the amount of simulator training given. It was applied to experimental results of another study (Provenmire and Roscoe 1973) and a good rough fit of the formula with the evidence was obtained.

In the present experiment, rated Army helicopter pilots

transitioning to the AH-1 helicopter were divided into two groups, of which one received training only in the aircraft (that is, simulated training = 0), while the other, experimental group, received training in the simulator prior to aircraft training. Within the simulator, three different levels of training--in terms of number of trials-- were given for each of 31 specific maneuvers, such that the amount of training time per maneuver could be compared with subsequently demonstrated proficiency in the aircraft, for that maneuver. Proficiency measurement was the number of aircraft trials required to reach criterion for the maneuver.

b. Results: Except for 3 maneuvers, 25 to 80 percent of the variance in aircraft training amounts required to reach criterion could be accounted for by the amount of prior simulator training for the maneuver.

The "goodness of fit" of the theoretical model for measuring training effectiveness was not easy to judge, expecially as the results of several of the maneuvers were very inconclusive due to obvious overtraining in the simulator which led to asymptotic performance in the aircraft. However, variance from performance as described by the model was less than significant at the a=.05 level on 31 maneuvers.

c. Authors' Conclusions: It should be pointed out there are other models and theoretical functions that would fit the data just as well or even better. However, there is no cogent reason for rejecting the model under consideration as a viable heuristic. From it, cost effectiveness of simulator time vis-a-vis time in the aircraft can be calculated.

Regardless of the intrinsic characteristics of the simulator, its effectiveness is a function of how it is used. The quantitative measures of effectiveness determined by this study are very much a function of how the instructor used the simulator as a training device. As simulator instructional tactics are refined, the device effectiveness should improve. The tradeoff curves determined by the study represent not the optimum effectiveness of this device, but the baseline effectiveness.

1. Author: Biersner, Robert J.

2. Title: Attitudes and Other Factors Related to Aviation Maintenance Training Effectiveness.

3. Source: Defense Technical Information Center Technical Report CNETS 6-75, December 1975.

4. Topic Keywords: Maintenance Training ; Attitudes ; Reinforcement ; Individualized Training ; Fidelity ; Media Comparison .

5. Short Summary: No significant differences were found between subjects trained on a moderate fidelity maintenance training device and controls trained on modified operational equipment, despite the fact that the subjects trained on the simulator were younger and less experienced. The subjects were tested for maintenance parts knowledge and some maintenance procedures, as well as their attitudes toward the training devices.

6. Devices:

a. EC2LP Simulator of Maintenance Equipment - (used by experimental subjects).

b. MTU Maintenance Training Unit (Operational Equipment Trainer used by controls).

7. Institutions:

a. Sponsor:
Naval Education and Training Support Command, Pensacola, FL.

b. Performing Organization: same

8. Type of Article: Experiment.

a. Number of Groups: 2

b. Description of Groups:
(1) Controls: 41 Enlisted male trainees attending O-level maintenance courses
(2) Subjects: 30 same

c. Measures and Timing of Measures: Pre-Test, Post-Test, and Post-Questionnaire

d. Number of Different Types of Measurements Used: 3

e. Description of Measurements and Ratings:

(1) Training Device Questionnaire
(2) Written pre-test and post-test (not identical for any one trainee); multiple choice
(3) Performance Post-Test

f. Experimental Setting/Training Context: Institutional classroom

g. Statistical Methods: T-tests; Pearson product-moment correlations; centroid solution to varimax rotation of items (questionnaire)

h. Variables Being Manipulated:
(1) Training Devices: EC2LP Simulator of Maintenance Equipment; MTU Maintenance Training Unit (Operational Equipment Trainer)
(2) Fidelity Levels:
(a) Physical: Moderate-High (of simulator)
(b) Functional: High (of simulator)
(3) Type of Task: Cognitive maintenance
(4) Task Difficulty: Medium
(5) Skills Required by Task: Perceptual, cognitive

i. State of Training: Familiarization

j. Trainee Sophisticitation: Intermediate

k. Incorporation of Device into P.O.I.: Lockstep

l. User Acceptance/Attitude: Moderately to highly favorable

m. Use of Instructional Features: Very incomplete

9. Abstract:

a. Study Synopsis: This study measured both the proficiency and attitudes toward training devices of subjects trained on one of two different devices being used for teaching maintenance knowledge factors. The control group, using operational equipment somewhat modified for training purposes (the MTU of Maintenance Training Unit) was in general more experienced and older than the experimental subjects, who used a simulator (EC2LP) of moderately high physical fidelity.

Testing consisted cf pre- and post- written tests (multiple choice, in which two similar tests were alternated between half the trainees before and after, so that no trainee took the same test twice, but each test was taken by equal numbers both before and after)

and a post-test of performance. All trainees also filled out a Training Device Questionnaire, the results of which were analyzed into 6 attitudinal factors: Reinforcement, Individualized Training, Media Comparison, Training Deficiencies, Utility, and Training Fidelity.

(1) Performance on tests: the two groups showed no significant differences related to the training devices. Some test scores, however, were found to be significantly related to the General Classification Test and the Mechanical Test of the Basic Test Battery; also to time in squadron (a measure of OJT) and to age.

(2) Attitudes:

(a) Trainees who rated the training devices better than books and/or charts performed better on both the written and performance tests than those trainees who judged books and charts to be better than the training devices.

(b) Trainees who were older and who had been in the Navy longer rated the two training devices as less suitable for individualized training than did younger trainees who had been in the service for a shorter period; trainees who had higher verbal intelligence (GCT) and higher mechanical aptitude (MECH) scores rated both of the devices as less deficient for training periods than those with lower scores; and trainees with higher arithmetic and mechanical aptitudes judged the devices higher in fidelity than did those with lower scores in these aptitudes.

(c) Both trainees and instructors favored the simulator over the operational equipment for training in every case.

Highly pertinent to the issue of simulation fidelity was the attitude of trainees regarding deficiencies in the operational equipment trainee vs. the simulator. These findings indicate that "although the EC2LP simulators have low structural fidelity, these simulators possess high functional fidelity which probably provides a better description than the MTUs of the integration of critical equipment parts with each other and with the aircraft as a whole.... It is likely... that differences in this training attitude were based largely on preconceived differences in the functional fidelity of the two devices."

teaching the night landing task via a transfer-of-training design, during the carrier qualification phase of Navy jet pilot training. The subject group of 26 trainees received device training prior to FCLP and carrier qualification flights in the A7E aircraft. The control group of 27 trainees received no device training. Within each group there was a subgroup of relatively inexperienced pilots ("Nuggets"), 13 in the experimental group and 16 in the control group.

Three different types of performance measures were taken during the FCLP and Carrier Qualification training flights in the A7E: (1) Attrition rate from the carrier qualification program; (2) landing ship officer scoring of candidates; (3) objective measures, of which the most important were the Boarding Rate (percentage of final approaches that resulted in successful landings) and the Landing Performance Score, an index of pilot performance derived from wire arrestment and bolter or waveoff data.

b. Results: Summary of A7E Landing Performance Measures and Statistical Results.

(1) Key Data:

	Mean Scores NCLT	Mean Scores No-NCLT	Stat. Sig.	Actual Diff.
Objective Measures				
Landing Performance Score				
Day CQ	4.60	4.65	N.S.	-0.05
Night CQ	4.27	3.90	$p < .02$	+0.37
Boarding Rate				
Day CQ	91.4	90.4	N.S.	+1%
Night CQ	76.7	69.3	$p < .05$	+7%
Attrition Measures				
Attrition First CQ	4%	30%		-26%
Success First CQ	96%	70%	$p < .006$	+26%
LSO Measures				
Day FCLP	2.88	2.90	N.S.	-0.02
Night FCLP	2.88	2.81	N.S.	+0.07
Day CQ	2.84	2.84	N.S.	0.0
Night CQ	2.76	2.47	$p < .003$	+0.29

(2) Verbal description: As indicated in the table above, the performance of the device-trained group in the night landing task during carrier qualification was significantly superior to the non-device-trained group in some of the principal performance measures; of which the attrition rate had probably the greatest practical importance.

e. Description of measurements and ratings:
   (1) Attrition rate
   (2) Subjective:
      (a) Landing Ship Officer scores
      (b) Student questionnaires
   (3) Objective:
      (a) Approach performance score
      (b) Landing performance score
      (c) Boarding rate
      (d) Bolter rate
      (e) Wire arrestment

f. Experimental setting/training context: institutional, hands-on.

g. Statistical methods: t-test; others not specified

h. Variables being manipulated
   (1) Training devices: as in section 6 above Subjects received training time on device prior to FCLP training; controls received no device training, nor substitute aircraft training
   (2) Fidelity levels
      (a) Physical: high
      (b) Functional: medium high to high
   (3) Type of task/skill required: operations, cognitive, psychomotor, perceptual, procedural, part-task
   (4) Task difficulty: medium-high to high

i. Stage of training: skill, transition, advanced

j. Trainee sophistication: intermediate

k. Incorporation of device into P.O.I.: lock-step

l. User acceptance or attitude
   (1) Instructor: favorable
   (2) Students: highly favorable as measured by questionaire

m. Use of instructional features
   (1) Intensity: intensive (assumed, not specified)
   (2) Features used: Freeze capability; Number/quality of reponses; Cue enhancement; Restart/resequence capability, modified to reenter only at one point

9. Abstract:

a. Study Synopsis: This study evaluated the effectiveness of a Night Carrier Landing Trainer in

1. Authors: Brictson, Clyde A. & Burger, William J.

2. Title: Transfer of Training Effectiveness: A7E Night Carrier Landing Trainer (NCLT) Device 2F103.

3. Source: NAVTRAEQUIPCEN Technical Report 74-C-0079-1, August 1976.

4. Topic Keywords: Transfer of Training ; Training Effectiveness ; Flight Simulation ; Night Carrier Landing .

5. Short Summary: A transfer-of-training evaluation of a Night Carrier Landing Trainer found the simulator effective in teaching the night carrier landing task to student pilots in the carrier qualification phase of training.

6. Devices:

a. A7E jet (transfer aircraft)

b. NCLT Night Carrier Landing Trainer, a part-task trainer with simulated cockpit, visual display system, 3 D.O.F. motion system, instructor console, and digital computer.

7. Institutions:

a. Sponsor: Naval Training Equipment Center, Code N-215, Orlando, FL 32813.

b. Performing Organization: Dunlap and Associates, Inc., Western Division, La Jolla, CA 92037.

8. Type of Article: Experiment.

a. Number of groups: 2

b. Description of groups:
(1) Subjects: 26 trainees in advanced navy jet pilot training (carrier qualification)
(a) 13 relatively inexperienced pilots
(b) 13 more experienced pilots
(2) Controls: 27 same
(a) 16 relatively inexperienced
(b) 11 more experienced

c. Tests or trials/timing: Post-tests (FCLP training and carrier qualification training flights)

d. Number of different types of measures: 3

b. Results: Both the mean and the standard deviation of the lateral position were significantly larger ($p<.01$) in the simulator than in the car, for both experienced and inexperienced drivers. The standard deviations of the yaw rate and steering wheel angle were significantly smaller ($p<.01$) in the simulator than in the car for the experienced drivers, whereas no significant differences were found between these variables for the inexperienced drivers. Greater driving experience did not affect the mean lateral position, but resulted in significantly smaller ($p<.01$) standard deviations for the lateral position, yaw rate, and steering wheel angle in the simulator. Driving experience had no effect on those measures in the instrumented car. The inexperienced drivers had a higher spectral density than the experienced drivers. This indicates a greater expenditure of energy in steering. Greater experience produces significantly smaller standard deviations ($p<.05$) for velocity and accelerator position in the simulator and the instrumented car. The experienced drivers maintained a more constant velocity.

Questionnaire opinions discriminated consistently and significantly between the simulator and the instrumented car for both groups. Drivers judged the simulator considerably more unfavorable than the instrumended car, with an exception for control of speed. Experienced drivers gave more favorable judgements than the inexperienced drivers ($p<.01$) on speed control.

There was a significantly high behavioral correlation between the two systems for all drivers (Pearson product-moment correlations were .36 for the mean lateral position, .57 for the standard deviation of the lateral position, .14 for the standard deviation of the yaw rate, and .32 for the standard deviation of the steering wheel angle, all significant, $p<.05$, except for the standard deviation of the yaw rate).

c. Author's Conclusions: A fixed-base simulator offers a valid method for studying straight road driving. Also, the simulator is more sensitive to differences between levels of driving experience than is the instrumented car on the road.

g. Statistical methods: Pearson product-moment correlations; Newman-Keuls tests

h. Variables being manipulated:
(1) Training devices: as in section 6 above.
Other variables:
(a) Lateral control requirement (suggested to one group within each main group by experimenter)
(b) "Longitudinal" control requirement (i.e., speed)

i. Stage of training: introduction

j. Trainee sophistication: novice and intermediate

k. Incorporation of device into P.O.I.: not applicable

l. User acceptance or attitude:
(1) Instructors: not applicable
(2) Subjects: moderately favorable to unfavorable

m. Use of instructional features
(1) Intensity: intensive
(2) Features used: Number/quality of responses; others not specified

9. Abstract:

a. Study Synopsis: This study was designed to evaluate the validity of an automobile driving simulator in the way in which it reproduced a behavioral environment.

A group of 24 very inexperienced drivers was compared with a group of experienced drivers in performance in driving along a straight road both in the simulator and in an instrumented car. Measurements were taken of the following dependent variables reflecting vehicle control: steering wheel angle, lateral position (distance between driver and right lane marker), yaw rate, position of acclerator, and velocity.

All subjects were also given questionnaires for evaluation of the device as to realism, difficulty, required attention, and monotony.

Task demands, in terms of verbal requests from the experimenter for straight or constant-speed driving, or both, were other independent variables of the study.

1. Author: Blaauw, Gerald J.

2. Title: Driving Experience and Task Demands in Simulator and Instrumented Car: A Validation Study.

3. Source: Human Factors , 1982, 24(4), 473-486.

4. Topic Keywords: Driving Simulation .

5. Short Summary: A driving simulator was compared with an instrumented car with drivers of varying expertise. The experiment found reasonable validity for the simulator and determined it to be more sensitive than the car to driver experience.

6. Devices:

   a. Fixed-base Automobile Driving Simulator.

   b. Instrumented Car.

7. Institutions:

   a. Sponsor: Institute for Perception TNO, Kampweg 5, Postbus 23, Soesterberg 3769 ZG, The Netherlands

   b. Performing Organization: same

8. Type of Article: Experiment.

   a. Number of groups: 2

   b. Description of groups:
      (1) Subjects: 24 experienced male drivers (licensed for a minimum of 3 years, had minimum 30,000 km experience)
      (2) Subjects: 24 inexperienced drivers (had at most just passed their driving test)

   c. Tests or trials/timing: 2 in-process trials (one each vehicle)

   d. Number of different types of measures: 2

   e. Description of measurements and ratings
      (1) Position of controls (steering wheel and accelerator)
      (2) Movement of car (lateral, longitudinal, yaw)

   f. Experimental setting/training context: laboratory, hands on

than in a comparable airplane under roughly comparable conditions. We cannot say with certainty why this is so. The data lead us to hypothesize that the observed differences between actual and simulated flight are due to higher levels of arousal in flight, which may have antagonized in part the effects of a depressant drug.

It is clear from data in this and other experiments (others cited include hypoxia and alcohol stress), that the GAT-1 simulator is a useful, sensitive, and comparatively inexpensive device for studies of the effects of mild stress on pilot performance. These data also suggest, however, that extrapolations from simulated to actual flight must be made with considerable caution. For example, it appears that experienced pilots in this study were able to compensate in part for the effects of a depressant drug when they were confronted with the threat factors inherent in the real world.

Data on lateral and angular deviations from localizer and glidepath centerlines, and on indicated airspeed, were recorded by an instrument. Data were evaluated by analysis of variance; correlations among the measures were evaluated by linear correlation analysis.

b. Results:

(1) Key Data:

Dep. Var.	Significance in Aircraft	Dose Effect (in mg.) in Aircraft		
		Best	Intermed.	Worst
DLA	0.01	100	0	200
SLA	0.01	0	100	200
DGA	n.s.	0	200	100
SGA	0.05	0	100	200
SDA	n.s.	200	100	0
SSA	0.05	100	0	200

Dep. Var.	Significance in Simulator	Dose Effect (in mg.) in Simulator		
		Best	Intermed.	Worst
DLA	0.05	0	200	100
SLA	0.05	0	100	200
DGA	0.01	0	100	200
SGA	0.01	0	100	200
SDA	0.05	0	100	200
SSA	0.01	0	100	200

DLA = mean absolute deviation from localizer centerline;
SLA = RMS variablity in localizer tracking;
DGA = mean absolute deviation from glidepath centerline;
SGA = RMS variablity in glidepath tracking;
DSA = mean absolute deviation from command airspeed;
SSA = RMS variability in airspeed.

(2) Verbal Description: With regard to the effects of barbiturates, it was immediately evident that the drugs exerted significant decremental effects on performance. The primary effect of drug was present to a significant degree in all six dependent variables in the simulator data, but in only four of the six variables in the aircraft data. The consistency of the drug-related effects was higher in the simulator data as well (see table above).

c. Authors' Conclusions: The effects of pharmacological stressors, particularly at low doses, may be observed more readily in the GAT-1 simulator

f. Experimental Setting/Training Context:
Experimental, laboratory and field

g. Statistical Methods: ANOVA; linear correlation analysis

h. Variables being manipulated:

(1) Training Devices: as in section 6 above; however, the variable of interest was the drug dosage:

(a) 0 dosage placebo
(b) 100 mg sodium secobarbitol
(c) 200 mg sodium secobarbitol

(2) Fidelity levels:

(a) Physical: of simulator, unspecified, presumably medium-high
(b) Functional: of simulator, unspecified, presumably high

(3) Type of Task/Skill required: aircraft piloting operations; cognitive, psychomotor, perceptual, procedural, part-task (aircraft landing approach)

(4) Task difficulty: high

i. Stage of Training: familiarization; skill

j. Trainee Sophistication: expert

k. Incorporation of Device into P.O.I.: not applicable

l. User Acceptance or Attitude: not discussed

m. Use of Instructional Features: unspecified

9. Abstract:

a. Study Synopsis: The purpose of this study was to assess the similarity between a simulator and an airplane in measuring the effects of stress--in this case, varying dosages of a depressant drug--on pilot performance.

Five highly experienced professional pilots, given three separate dosages of sodium secobarbitol (0 mg placebo, 100 mg, 200 mg) in a single-blind design, were required to make instrument landing approaches in the Link-Singer GAT-1 light airplane simulator, and, at a different site and time, in an instrumented Cessna model 172. The pilots had been given prior familiarization with both simulator and airplane.

1. Authors: Billings, Charles E., Gerke, Ralph J., & Wick, Robert L. Jr.

2. Title: Comparisons of Pilot Performance in Simulated and Actual Flight.

3. Source: Aviation, Space, and Environmental Medicine, March 1975, 304-308.

4. Topic Keywords: Drug-related Effects ; Flight Simulation ; Instrument Landing ; Instrument Flight Simulation .

5. Short Summary: This experiment comparing the performance of pilots under drug stress in a GAT-1 simulator and an airplane suggests that the GAT-1 simulator may be a sensitive device for studying the effects of mild stress on pilot performance.

6. Devices:

a. Link-Singer GAT-1 light airplane instrument flight simulator

b. Cessna Model 172 fully equipped for instrument flight

7. Institutions:

a. Sponsor: Aerospace Medical Research Laboratory, Aerospace Medical Division, Air Force Systems Command, Wright Patterson AFB, OH.

b. Performing Organization: Department of Preventive Medicine, Ohio State University, Columbus, OH 43210, Man-Machine Integration Branch, Ames Research Center, Moffet Field, CA 94035

8. Type of Article: Experiment.

a. Number of Groups: 1

b. Description of Groups: 5 highly experienced professional pilots

c. Tests or Trials/Timing: 2 test flights

d. Number of Different Types of Measures: 1

e. Description of Measurements and Ratings: Instrument-recorded quantified data: airspeed and deviations from landing approach path.

were being taught as well as familiarization with equipment, although the former was not officially recognized as an objective of training. Cost-effective use of the simulator requires matching specific capabilities of the simulator with identified training requirements. When the simulator capabilities are not incorporated into the design of the training program, or the training requirement are not precisely identified, use of the simulator will fall short of optimum effectiveness.

b. Results: No statistical measures are reported. No salient differences in effectiveness were observed between the simulator and conventional classroom training, according to the author. Subjectively, both instructors and students were pleased with simulator use, but did not put forward arguments clearly favoring it over other training aids.

c. Authors' Conclusions: A formal, summative evaluation of the training effectiveness of the ECII-LP simulators should probably not be undertaken until minor modifications have been made in the design and support of the ECII-LPs, and some major modifications have been instituted in the management and delivery of the existing training courses for pilots and Naval Flight Officers. At the time of the study, certain deficiencies in the simulator lowered instructor and student morale, and instructors were not sufficiently knowledgeable about the simulator's capabilities. These problems require correction at a technical and at a formal level.

g. Statistical Methods: none used

h. Variables Being Manipulated:
(1) Training Devices: Flight Cockpit Display Simulator ECII-LP
(2) Fidelity Levels: medium to high
(3) Type of Task: familiarization with display and some procedural tasks
(4) Task Difficulty: moderate

i. Stage of Training: pre-flight

j. Trainee Sophistication: highly varied

k. Incorporation of Device into P.O.I.: instructor-managed

l. User Acceptance or Attitude:
(1) Instructors: instructors complained about technical deficiencies of the device
(2) Students: good

m. Use of Instructional Features:
(1) Intensity: incomplete
(2) Features used: interactive capability; others not specified

9. Abstract:

a. Study Synopsis: The author states, "this report is essentially a formative review, based on observations and interviews rather than test scores or other objective quantifiable information." The tenor of the observations is as follows:

(1) Instructor Findings: The simulator made presentation of information better organized and more convenient than other training aids. Instructors were disturbed by a technical deficiency of the simulator which made them appear incompetent. Instructor Managed Instruction is indicated in preference to standard lecture procedures.

(2) Student Findings: Students receiving simulator [illegible]ining were less confused than the controls, as indicated by fewer and more sophisticated questions and other subjective evidence.

(3) Other Observations: The capabilities of the simulator were not being fully realized; in particular the computer-programmed interactive capability. The skills being learned were not clearly defined; e.g., basic cockpit procedures

1. Author: Biersner, Robert J.

2. Title: Observations on the Use and Evaluation of ECII-LP Simulators for Aviation Training.

3. Source: Chief of Naval Education and Training Support Report 2-76, 1976.

4. Topic Keywords: Display Systems ; Visual Aids ; Flight Simulators ; Human Factors ; Participant-Observer .

5. Short Summary: Simulator training proved to be no more effective than conventional classroom training for learning the subject task. However, the program using the simulator was hampered by lack of integration into the program, instructors lack of knowledge of the training device, and other correctible shortcomings. A more extended implementation is recommended.

6. Devices: Flight Cockpit Simulator ECII-LP

7. Institutions:

   a. Sponsor: Chief of Naval Education & Training Support, Pensacola, FL.

   b. Performing Organization: NAVTRADET 1048, Sherman Field, Naval Air Station, Pensacola, FL.

8. Type of Article: Experiment.

   a. Number of Groups: 2

   b. Description of Groups:
      (1) Subjects: 6 Navy and Marine undergraduate student pilots
      (2) Controls: 30 Navy and Marine undegraduate student pilots

   c. Tests or Trials/Timing: post-test evaluations

   d. Number of Different Types of Measures: 3 (nonquantitative evaluations)

   e. Description of Measurements and Ratings:
      (1) Student interviews
      (2) Student questionnaires
      (3) Instructor evaluation reports

   f. Experimental Setting/Training Context: school

b. Results:

	SIM GROUP (N=30) Mean	SIM GROUP (N=30) Standard Deviation	MTU GROUP (N=41) Mean	MTU GROUP (N=41) Standard Deviation
Written Pre-Test	17.48	7.02	18.33	5.23
Written Post-Test	34.35	3.95	34.73	3.75
Performance Test	75.81	15.30	77.75	21.31

Verbal Description: "Training effectiveness... was similar for the EC2LP simulators and MTUs despite differences between the two training groups in age, pay grade, and years of naval service. Previous squadron experience, which is an index of on-the-job training, was found to improve scores on... tests for both training device groups. More general training experience... appeared to be especially important to better performance test scores. Trainee acceptance of the two devices appears to be related not only to characteristics of the devices, but to intelligence, aptitudes, and previous military experience.... Trainees with higher mechanical and arithmetic aptitudes find training devices to be high in training fidelity."

c. Author's Conclusion: Apparently the two training devices compared in this evaluation can be used in aviation maintenance courses with equal training effectiveness. The substitution of the EC2LP simulator for the MTU would be a highly cost-effective procedure. This recommendation, however, assumes that the criteria of training effectiveness (written and performance tests) are valid measures of the training objectives.

The absence of structural fidelity in the simulators does not impair trainee attitudes toward the device. Instructor attitudes, as well as design features of the simulator, indicate that this device could be used more for individualized training.

Other measures not shown in the table above showed either no significant differences between groups, or showed superiority for the experimental, device-trained group.

An especially interesting finding was that the device training had no measurable significant effect on performance in day landings.

The difference between the relatively untrained "Nugget" subgroups was even more pronounced than for the main groups; almost half of the Nuggets (44%) in the no-NCLT group failed to qualify on the carrier, compared with only 8% of the device-trained Nuggets; and the one failure among the device-trained Nuggets was disqualified on the day portion.

c. Authors' Conclusions: It is clear that positive NCLT transfer of training was demonstrated. This was especially true for the less experienced pilots. The data suggest that NCLT training can be combined with FCLP training and in some cases perhaps be used to supplant some FCLP night work. This would appear more feasible with the more experienced pilots as these were scored consistently higher than the less experienced pilots by the Landing Ship Officers across all FCLP periods.

Day FCLP and CQ performance did not change as a result of NCLT training. This seems to indicate that NCLT training in night procedures and visual cues does not transfer to day landing performance.

1. Authors: Browning, Robert F., Ryan, Leonard E., Scott, Paul G., & Smode, Alfred F.

2. Title: Training Effectiveness Evaluation of Device 2F87F, P-3C Operational Flight Trainer.

3. Source: Training Analysis and Evaluation Group Report No. 42, January 1977.

4. Topic Keywords: Visual Flight Simulation ; Transfer of Training ; Proficiency-based Training ; Training Effectiveness .

5. Short Summary: This transfer-of-training comparison of a high fidelity flight simulator with an older, more limited flight simulator found that the high fidelity simulator was more effective as a trainer.

6. Devices:

   a. P-3 turboprop aircraft - the transfer environment

   b. Device 2F87F , High Fidelity Digital Operational Flight Trainer, with visual and 6 degrees-of-freedom platform motion capability.

   c. Device 2F69D Analog Operational Flight Trainer with no visual simulation and 3 degrees-of-freedom motion.

7. Institutions:

   a. Sponsor: Training Analysis and Evaluation Group, U.S. Navy, Orlando, FL 32813.

   b. Performing organization: same

8. Type of Article: Experiment.

   a. Number of groups: 2

   b. Description of Groups:
      (1) Subjects: 27 newly designated first-tour naval aviators
      (2) Controls: 16 same concurrent controls
      (3) 58 same historical controls

   c. Tests or trials/timing: post-tests

   d. Number of different types of measures: 4

   e. Description of measurements and ratings
      (1) Check flight grades

(2) Number of flights and landings to criterion proficiency
(3) Number of specific tasks on which students were judged proficient
(4) Errors per landing

f. Experimental setting/training context: Institutional, hands-on

g. Statistical methods: not specified

h. Variables being manipulated
(1) Training devices: as above section 6
(2) Fidelity levels

	Physical	Functional
2F87F	High	High
2F69D	Medium	Medium

(3) Type of task/skill required: aircraft piloting operations, cognitive, psychomotor, perceptual, whole-task
(4) Task difficulty: High

i. Stage of training: transition

j. Trainee sophistication: intermediate

k. Incorporation of device into P.O.I.: lock-step

l. User acceptance or attitude:
(1) Instructors: very favorable as measured by questionnaire
(2) Students: not discussed

m. Use of instructional features:
(1) Intensity: incomplete
(2) Features used: not specified

9. Abstract:

a. Study Synopsis: This study undertook to compare the training effectiveness of a new state-of-the-art high fidelity simulator, Device 2F87F, with that of an older, less versatile and realistic simulator, Device 2F69D, in transitioning first-tour naval aviators to the P-3 turboprop aircraft. The chief difference between the two devices was the visual flight capability of the newer 2F87F, whereas the 2F69D had no visual capability.

A group of 27 trainees were trained on the 2F87F, while

concurrently a group of 16 control subjects were trained on the older 2F69D; an "historical" group of 58 control subjects, previously trained on the same syllabus, was also compared with the experimental subjects on certain measures. Classroom and cockpit familiarization and procedures instruction was the same for both groups. However, the experimental group received six sessions in the 2F87F simulator, in accordance with a new syllabus designed for that device, whereas the control group received only 3 sessions in the 2F69D simulator.

The performance of both groups were measured after transfer to P-3 aircraft flying training, in terms of checkflight grades, number of aircraft flights and landings to criterion proficiency, number of check tasks in which students were judged proficient, and errors during landings.

b. Results:

(1) Key Data: Flight Hours and Flight Grades of Control and Experimental Groups

	Historical Controls	Concurrent Controls	Experimental Subjects
Number of Students	58	16	27
UPT Basic & Advanced Flight	55.8	55.8	54.2
Flight Hrs. per Student (P-3)	15.1	14.5	8.8
Check Flight Grade (P-3)	3.02	3.02	3.03

** averages **

(2) Verbal Description: The experimental group average of 8.6 hours in aircraft represents a savings of 40.6 hours over the concurrent controls and 43 percent over the historical controls. The average check flight score did not differ significantly from that of the control groups.

In regard to proficiency on specific check tasks during aircraft flight, every one of 20 check tasks was judged proficient for the experimental group in fewer flights than for the concurrent control group (no data from the historical control group was available on this measure). A comparison of the Standard Deviations of the

experimental and control group suggests that Device 287F reduces the average training time difference between "fast" and "slow" learners. The average number of aircraft landings for the experimental group was 36; for the Control group, 52; a 31% savings.

A cost analysis was also conducted which showed the savings in aircraft flying time resulting from the use of the new simulator would yield substantial savings, far offsetting the increased cost of the new simulator.

In only 50 instances out of 1,200 gradings were students given a below average grade on a task that had previously been graded proficient. The subsequent lowering of a grade to below average after proficiency is achieved occurred less than 5% of the time.

c. Author's Conclusions: The combination of six simulator and four aircraft flights will maintain current standards and achieve a $40 million savings over a 10-year period.

Flight time can be reduced by training each task to proficiency in Device 2F87F prior to that task being checked or trained in the aircraft. The ultimate reduction in aircraft training time may be achieved only through proficiency-based training. Although conversion to a train-to-proficiency concept presents a number of formidable problems, it has merit and warrants strong consideration.

1. Authors: Burger, William J. & Brictson, Clyde A.

2. Title: A7E Transfer of Training Effectiveness: Device 2C15A CPT and Device 2F84B OFT/WST.

3. Source: NAVTRAEQUIPCEN 74-C-0079-2, August 1976

4. Topic Keywords:` Transfer of Training ; Flight Simulation ; Training Effectiveness .

5. Short Summary: A qualitative evaluation of two flight simulators reveals limitations of the devices and recommends some steps for improvement; however, the qualitative methodology fails to determine the training efficiency of the devices.

6. Devices:

a. 2C15A Cockpit Procedures Trainer

b. 2F84B Operational Flight Trainer / Weapon System Trainer

7. Institutions:

a. Sponsor: Naval Training Equipment Center, Orlando, FL 32813

b. Performing Organization: Dunlap and Associates, Inc., Western Div., 115 So. Oak St., Inglewood, CA 90301

8. Type of Article: Survey.

Researchers reviewed training methods, materials, and observed actual training sessions. Interviews were conducted with experienced Phase Officers and 13 Instructor Pilots.

a - d: not applicable

e. Description of Measurements and Ratings: subjective assessments of device effectiveness and characteristics

f. Experimental Setting/Training Context: not applicable

g. Statistical Methods: not applicable

h. Variables Being Manipulated:
(1) Training Devices: as above, section 6

(2) Fidelity Levels:
CPT OFT/WST (a) Physical: High High (b) Functional: Low Medium (3) Type of Task/Skill Required:
(a) CPT - perceptual, cognitive, procedural
(b) OFT/WST - operations, cognitive, psychomotor, procedural
(4) Task Difficulty:

i. Stage of Training:
(1) CPT - introduction, nomenclature, procedural, familiarization
(2) OFT/WST - skill, transition

j. Trainee Sophistication: novice for CPT; intermediate for OFT/WST

k. Incorporation of Device into P.O.I.: not specified, assumed lock-step

l. User Acceptance or Attitude:
(1) Instructors: generally not favorable to CPT; moderately favorable to OFT/WST
(2) Students: not discussed

m. Use of Instructional Features:
(1) Intensity: incomplete due to equipment malfunctions and instructor distrust
(2) Features used:
CPT: not specified
OFT/WST: Freeze capability; Record/Playback

9. Abstract:

a. Study Synopsis: The study objective, to assess the transfer of training effectiveness of two A7E aircraft simulators, was hindered by barriers to conducting a controlled quantitative study. The researchers chose as an option a qualitative methodology developed by G.G. Jeantheau, described as "Level One Evaluation, Qualitative Assessment," comprising the following parts:
(1) establishing the purpose of training;
(2) identifying design features that contribute to or hinder training effectiveness;
(3) identifying features of training practice of use of the device which contribute to or hinder training.

The researchers reviewed training methods and materials, observed actual training sessions, and conducted intensive interviews with Phase Officers and

experienced Instructor Pilots. The study focussed on specific design and utilization factors rather than on overall effectiveness, since the subjective nature of the evaluation dictated that attempts at assessing the latter would produce inconclusive results at best.

b. Results: One important finding of the study was the consensus among all personnel involved that the Cockpit Procedures Trainer was overdesigned and overly expensive for the simple nomenclature and procedural tasks which it taught. The Operational Flight Trainer/Weapons Systems Trainer was judged by instructors to be indispensable for pilot training, yet a large number of deficiencies were cited that begged for improvement.

c. Authors' Conclusions:

(1) Devices: The current Cockpit Procedures Trainer is best left alone. Its contribution to overall training is relatively small, and enhancement of its capability appears more costly, even if feasible, than the potential payoffs seem to warrant. The Operational Flight Trainer/ Weapons Systems Trainer's integral relationship to flight training suggests that consideration be given to remedial action relative to several problems identified.

(2) Evaluative Method: The heart of the training effectiveness methodology was assessment of whether the following criteria were met: (a) prespecified training objectives, (b) structure and control, and (c) feedback and sequencing based on objective performance measurement.

In the case of the devices under study, application of the criteria seem superficial and unproductive. The real question of interest is efficiency, not effectiveness, about which the method does not make claims. An important improvement to the method, if the checklist is to assist in evaluation, is a description of "accepted training principles" and an improved method for determining their influence on device effectiveness.

The authors found that interview data obtained from critiques by Phase Officers and Instructor Pilots were more informative with regard to training efficiencies, problem areas, and implications for future simulator design, than the checklists.

1. Author: Caro, Paul W.

2. Title: Equipment-Device Task Commonality Analysis and Transfer of Training.

3. Source: Human Resources Research Organization , HUMRRO Technical Report 70-7, June 1970.

4. Topic Keywords: Task Commonality ; Transfer of training ; Flight Simulation .

5. Short Summary: A commonality analysis was performed on a training device that was previously judged deficient in transferring training. This analysis establishes the source of the deficiency as a lack of commonality between training device controls and rotary wing aircraft controls.

6. Devices:

a. Army TH-13T helicopter (transfer equipment)

b. 1-CA-1 Fixed Wing Instrument Trainer (modified for rotary wing instruction)

7. Institutions:

a. Sponsor: Office, Chief of Research and Development, Department of the Army, Washington, DC 20310.

b. Performing organization: Human Resources Research Organization , 300 North Washington Street, Alexandria, VA 22314.

8. Type of Article: Analytical.

9. Abstract: The implementation of procedures for task-commonality analysis arose out of an evaluation of a specific training device used in Army helicopter training. The device, the 1-CA-1, orginally a fixed-wing instrument trainer, had been modified for helicopter instrument training, but had been found deficient in producing transfer of training to the rotary-wing aircraft. This paper describes the method used to analyze the deficiencies with the hope of altering the training program to compensate for them.

Lists were made both of hardware stimuli (displays) and non-hardware (environmental) stimuli, and of controls in the trainer and the aircraft, and the lists were compared. An analysis was made of criterion maneuvers in the aircraft to determine what displays and controls (stimuli and responses)

were used to execute the maneuvers. Assessments as to the realism of relevant device components were made by helicopter instructor pilots.

The information was analyzed on the basis of two transfer-of-training assumptions:

a. Postive transfer will occur when both stimuli and responses are similar in the training situation and the criterion situation;

b. Negative transfer will occur when the stimuli are similar in the training and the criterion situations, but the responses to the similar stimuli are different.

It was judged that the deficiency in the trainer resulted principally from a lack of commonality between the controls of the device and the aircraft. Of seven controls identified as important in the performance of criterion maneuvers, all of which were present in both aircraft and training device, three were rated in the training device as unrealistic in either direction of motion or effect on displays. In addition, an eighth control, the throttle, was not even present in the training device.

The dissimilarities in the controls were so critical as to preclude the attempt to develop a new training program using the device. It was felt that unacceptable negative transfer would result no matter what revisions were made in the training program. Recommendation was to use the device as a procedures trainer, and only in adjunct to real- aircraft flight training.

1. Author: Caro, Paul W.

2. Title: Transfer of Instrument Training and the Synthetic Flight Training System.

3. Source: Human Resources Research Organization , HUMRRO Professional Paper 7-27, February 1972.

4. Topic Keywords: Instrument Flight Simulation ; Transfer of Training ; Criterion Based Training .

5. Short Summary: A criterion-performance-based training program tailored to make optimal use of a sophisticated instrument flight simulator was found to be dramatically effective in teaching student pilots the instrument phase of helicopter flight.

6. Devices:

a. Army Synthetic Flight Training System (trainer)

b. UH-1H helicopter (test device)

7. Institutions:

a. Sponsor: Office of the Chief of Research and Development, Department of the Army, Washington, DC 20310.

b. Performing Organization:
Human Resources Research Organization , 300 North Washington Street, Alexandria, VA 22314.

8. Type of Article: Experiment.

a. Number of Groups: 1

b. Description of Groups: The Subjects: 16 candidates, Officer Rotary Wing Aviator Course, transitioning from primary contact training to instrument flight in helicopter

c. Tests or Trials/Timing: 1 in-process simulator test (checkflight in simulator); 1 post-test (checkflight in aircraft)

d. Number of different types of measures: 2

e. Description of Measurements and Ratings:
(1) Time to criterion and amount of time in checkride
(2) Checkride grade scored by instructor pilot

f. Experimental setting/training context: Institutional, hands-on

g. Statistical methods: Product moment correlation; others not specified

h. Variables being manipulated:
(1) Training Device: Synthetic Flight Training System
(2) Fidelity Levels:
(a) Physical: unspecified, presumably high
(b) Functional: unspecified, presumably high
(3) Type of task/skill required: helicopter piloting, operations, cognitive, psychomotor, perceptual, procedural, part-task
(4) Task Difficulty: High

i. Stage of Training: skill, transition

j. Trainee sophistication: intermediate

k. Incorporation of device into P.O.I.: instructor-managed

l. User acceptance or attitude: not discussed

m. Use of instructional features:
(1) Intensity: not specified, presumably intensive
(2) Features used: not specified

9. Abstract:

a. Study Synopsis: The purpose of this study was to evaluate, not only a sophisticated helicopter instrument flight training simulator, but also a newly-designed training program which was tailored to make optimal use of the device. Fundamental to the new program design was individualized instructor-managed training, where student advancement through the program was geared to the achievement of criterion proficiency--a departure from the lock-step program which was standard at the time of the study.

16 Army helicoptr trainees who had completed their primary phase of helicopter flight training were selected to take the experimental course of instruction in place of the standard instrument-flight-phase course of instruction. Instead of the standard 60 hours aircraft time plus 26 hours simulated training on the old device, the subjects received a mean of 6 1/2 hours aircraft time and 42 hours simulated training in the

Synthetic Flight Training System (SFTS), including time for checkrides.

b. Results:

(1) Key Data:

Training Time Requirements in the SFTS and Grades of Students in Simulated Checkride in SFTS: (in hours/minutes)

	Mean	Std. Deviation
Training Time	40/28	3/41
Checkride Time	2/22	/38
Total Time	42/50	3/47
Checkride Grade	84.2	7.6

Aircraft Familiarization and Checkride Time Requirements and Grades of Students in the UH-1

	Mean	Std. Deviation
Training Time	4/12	1/21
Checkride Time	2/15	/30
Total Time	6/27	1/31
Checkride Grade	82.0	6.2

(2) Verbal Description: All of the experimental students passed their checkrides. The means of their performance in the simulator and aircraft are shown above.

c. Author's Conclusions: The study provides evidence that simulators can be used as effectively with undergraduate Army trainees as with highly experienced commercial pilots. In fact, as far as the Instrument Phase is concerned, the Army undergraduate training in the experiment was significantly more effective than the conventional training.

"It should be obvious that the manner in which the device was used contributed to these results perhaps as much as the equipment itself. Undoubtedly, had any existing synthetic training program been used, much of the potential effectiveness of the SFTS would have been lost," wrote the author.

The entire training program was criterion-performance oriented, and so unconventional that considerable doubt was expressed by experienced aviators concerning its workability. Their doubts have been resolved by the results obtained.

It is clear that military pilot training organizations can make much more extensive use of aircraft simulators in their under-graduate pilot training programs.

improvements were made in the simulator itself (to improve its physical fidelity and to quicken its response), and major changes were made in the P.O.I.

To the end of improving the P.O.I. to make best use of all T.D.'s simulators in particular, "an explicit statement of minimal trouble-shooting standards should be made".

b. Results:

(1) Key Data: Overall trouble-shooting test proficiency as a function of training and testing modes

TOTAL TEST SCORES

Test Mode		Training Mode: Actual Equip.	Training Mode: Simulator
Actual	N	24	28
	Mean	23.56	22.82
	SD	1.86	1.47
Simulator	N	29	28
	Mean	22.66	22.86
	SD	1.56	1.53

TOTAL TIME TO COMPLETION (MINUTES)

Test Mode		Actual Equip.	Simulator
Actual	N	24	18
	Mean	50.21	53.75
	SD	9.14	7.72
Simulator	N	29	28
	Mean	58.10	55.93
	SD	7.81	9.66

(2) Verbal Description: The only significant differences found between simulator-trained and actual- equipment-trained students on any performance measures were in scores and time taken in the trouble shooting test when done on actual equipment (see above), and these differences were very slight. "This effect is minor... and may be the result of machine-specific experience rather than qualitative differences in training."

In the attitude questionnaire, there was little difference in students' attitudes toward the two devices. Instructors, however, were more critical of the simulator, particularly as the simulator was deficient in response-time.

A life-cycle cost analysis showed the simulator to be no more than half as expensive as the actual equipment then in use as a training device.

c. Authors' Conclusions: At the intermediate-introductory level of training where this study was made, no practical advantage is to be found in the use of actual equipment rather than the simulator. The authors suggest three scenarios for incorporation of the simulator in the P.O.I.: (1) to add simulators over and above existing actual equipment training devices; (2) to combine the actual equipment training devices and the simulators in a complementary fashion; (3) to replace the actual equipment T.D.'s with simulators. This last and most revolutionary option would serve most effectively if some

m. Use of Instructional Features:
   (1) Intensity: incomplete
   (2) Features used: not specified

9. Abstract:

a. The objective of the study was to determine the relative effectiveness of a 3-dimensional simulator and the 6883 actual equipment test station on dimensions of instructional efficiency, attitudinal acceptance, field performance of simulator-trained personnel, and life cycle costs.

Four groups of 28-30 aviation maintenance trainees each were trained and tested either on the simulator or on the actual equipment which was the standard device used in the curriculum. One group was both trained and tested on the simulator; another was both trained and tested on the actual equipment; one group was trained on the simulator and tested on the actual equipment; and the last group trained on the actual equipment and tested on the simulator.

In addition to the troubleshooting proficiency test on the devices, the trainees were tested by a 70-item pencil and paper test (short answer and multiple choice). Additional measurements were: students' scores during subsequent training blocks; and field/OJT evaluation by supervisors in the field. Furthermore, students evaluated their own training via questionnaires immediately after the experiment and later in the field; instructors evaluated the training via questionnaire.

Great care was taken, by procedural and statistical methods, to weigh and where possible eliminate the following variables as significant factors in the results: training sequence; student aptitude; student sex bias; prior adjustment bias. "Further correlation analyses showed that even in those cases where it might be argued that a slight bias existed, variables were not meaningfully related to performance on the trouble- shooting test."

(b) 29 same, AET-trained and simulator-tested

c. Tests or Trials/Timing: Two immediate post-tests; delayed field/OJT evaluation

d. Number of different types of measures: 4

e. Description of Measurements and Ratings:
(1) Trouble-shooting test, hands-on 29-item task
(a) total score
(b) total time
(c) degree of instructor assistance required
(2) Projected Job Proficiency 70-item pencil & paper test
(3) Subsequent training instructional block scores
(4) Questionnaires answered by field supervisory personnel

g. Statistical Methods: Chi-Square; ANOVA; Point-Biserial Correlations; Fisher's Method of Adjustment

h. Variables Being Manipulated:
(1) Training Devices:
(a) 6883-3D three dimensional maintenance troubleshooting simulator for F-111
(b) Actual Equipment Training Device (AET)
(2) Fidelity Levels:
(a) Physical: for simulator, medium
(b) Functional: for simulator, medium-high (slow reaction)
(3) Type of Task/Skill Required: maintenance trouble- shooting; cognitive; psychomotor; motor; perceptual; procedural; part-task
(4) Task Difficulty: unspecified; presumably medium- high

i. Stage of Training: introduction; procedural; skill

j. Trainee Sophistication: intermediate

k. Incorporation of Device into P.O.I.: lock-step and instructor-managed

l. User Acceptance or Attitude:
(1) Instructors: Reluctant to accept simulator as replacement for actual equipment; critical of some functional deficiencies (esp. slowness of simulator response)
(2) Students: good

1. Authors: Cicchinelli, Louis F., Harmon, Kenneth R., Keller, Robert A., & Kottenstette, James P.

2. Title: Relative Cost and Training Effectiveness of the 6883 Three-Dimensional Simulator and Actual Equipment.

3. Source: Air Force Human Resources Laboratory TR-80-24, September 1980.

4. Topic Keywords: Three-dimensional Simulator ; Training effectiveness ; Maintenance Training ; Trouble-shooting ; Maintenance Simulation .

5. Short Summary: This experiment compared test performance and other proficiency measures from groups of maintenance students. These groups were instructed either on actual maintenance test station equipment or a three-dimensional simulator. The experiment found significant differences in only one task; yet using actual equipment was twice as expensive as using the simulator.

6. Devices:

a. 6383-3D Three dimensional maintenance simulator for F-111

b. 6883 Actual equipment test station training device (AET)

7. Institutions:

a. Sponsor: HQ Air Force Human Resources Laboratory , Brooks AFB, TX.

b. Performing Organization:
Denver Research Institute, Social Systems Research and Evaluation Division, University of Denver, Denver, CO 80208

8. Type of Article: Experiment.

a. Number of Groups: 4

b. Description of Groups:
(1) Subjects:
(a) 28 F-11 Avionics Maintenance trainees, simulator-trained and Actual Equipment-tested
(b) 28 same, simulator trained and simulator tested
(2) Controls:
(a) 30 same, AET-trained and AET-tested

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were not cited.)

The results confirmed the cost-effectiveness of designing and implementing new training programs to suit the capabilities of new training devices. The training program used with a device is at least as important as the device itself.

b. Results: Four experimental subjects in a newly designed training program using new simulation training device reached check flight criterion in aircraft with considerably less hands-on aircraft instruction time than students in the older training program using either old or new equipment.

Key Data: Training Hours Required to Reach Criterion

	Aircraft	Device	Classroom
Existing Program	60:00	21:00	90:00
Experimental			
Trainee No. 1	33:55	19:00	39:00
Trainee No. 2	34:05	19:30	39:00
Trainee No. 3	34:30	21:00	39:00
Trainee No. 4	35:10	21:00	39:00

c. Authors' Conclusions: The training program used with a device is more important, from the transfer of training viewpoint, than the device itself.

h. Variables Being Manipulated:
(1) Training Devices: Off-the-shelf fixed wing synthetic instrument flight procedure trainer GAT-2; however, the variable of interest was the training program itself, rather than the device.
(2) Fidelity Levels: Unspecified. Presumed high.
(3) Type of Task/Skill Required: Instrument Flight Procedures
(4) Task Difficulty: Medium-High

i. Stage of Training: transition from single-engine to twin-engine fixed wing aircraft

j. Trainee Sophistication: Medium-high

k. Incorporation of Device into P.O.I.: Lock-step

l. User Acceptance or Attitude:
(1) Instructors: not discussed
(2) Students: not discussed

m. Use of Instructional Features:
(1) Intensity: intensive
(2) Features used: not specified

9. Abstract:

a. Study Synopsis: Although it has long been known that factors other than equipment/simulation device similarity impact on transfer of training, study of those other factors is seldom sufficient. When a new training device appears, program designers and administrators tend to rely upon the device itself to assure adequate training.

In this study, a follow-up to an experimental study which established the training effectiveness of the then- new GAT-2 Instrument Flight Simulator, a training program was designed and implemented specifically to exploit the advantages of the new device over an old device then in use in a routine school program.

The new program has 25 hours less aircraft time (and also quite a bit less classroom time) than the routine program, while training device time on the new device was somewhat above training device time on the old device in the routine program. Four subjects trained experimentally under the new program were able to meet check flight criterion after completion. The savings in real-aircraft flight training due to the new program was calculated to be roughly $1,000 per trainee. (Data on the relative costs of the old versus new simulator

1. Authors: Caro, Paul W., Isley, Robert N., & Jolley, Oran B.

2. Title: Research on Synthetic Training: Device Evaluation and Training Program Development - (Study Two).

3. Source: Human Resources Research Organization Technical Report 73-20, September 1973, pp. 23-32.

4. Topic Keywords: Instrument Flight Simulator ; Transfer of Training ; Program Design ; Training Program .

5. Short Summary: This report on the implementation of a newly designed training program employing a new simulator training device attempts to demonstrate that how the training program uses a device is more important, from the transfer of training viewpoint, than the device implementation itself.

6. Devices: Off-the-shelf Fixed Wing Simulator for instrument flight procedure training.

7. Institutions:

a. Sponsor: Office of the Chief of Research and Development, Department of the Army

b. Performing Organization: Human Resources Research Organization Division No. 6 (Aviation), Fort Rucker, AL 36362

8. Experiment:

a. Number of Groups: 1

b. Description of Groups:
(1) Subjects: 4 trainees, Officer/Warrant Officer Fixed Wing Aviator Course
(2) Controls: Post-test

c. Tests or Trials/Timing:

d. Number of Different Types of Measures: 1

e. Description of Measurements and Ratings: training hours to criterion

f. Experimental Setting/Training Context: Institutional, hands-on

g. Statistical Methods: not specified

evaluation, the experimental subjects showed significantly superior performance to the controls. Although equipment and administrative limitations precluded clearly valid comparisons with any group who received routine training on the old simulator, the performance of the experimental subjects appeared roughly at least equal to the performance of those under going the routine training on the old simulator.

The study concluded that the design and implementation of a new training program, to exploit advantages of the new, higher-fidelity training device, was warranted. This undertaking is reported in "Study Two" of the same Technical Report, which is summarized in another abstract (same title, "Study Two").

b. Results: Trainees who received training in the new device, compared with control group trainees (no simulation training), had a lower attrition rate and were more likely to be above-average students, according to flight instructor's ratings. In check rides, experimental subjects performed better at procedural tasks when evaluated subjectively by check pilots and when scored objectively from photographic records of check ride.

Key Data: Flight Deficiency Attrition

Group	Number Entering Training	Attrition Stage One	Attrition Stage Two	Total
Environmental	24	1 ($p < .05$)	1	1
Control	16	5	0	5

c. Authors' Conclusions: The new device can contribute to the effectiveness of twin-engine transition and instrument training. When the device is used with a training program employing modern training concepts, significant savings to the Army in inflight training time can be obtained.

There has been no evidence presented in this research that synthetic training in the new device is more effective than similar training in existing equipment. Nevertheless, on the basis of its greater overall task similarity to that required in the training aircraft, one would predict greater transfer from the new device.

(2) Supervisor Ratings: Check Pilot Checklists; Instructor Questionnaires; Instructor-assigned daily flight grades

f. Experimental Setting/Training Context: School

g. Statistical Methods: ANOVA

h. Variables Being Manipulated:
(1) Training Devices: Off-the-shelf fixed wing synthetic instrument flight procedure trainer GAT-2
(2) Fidelity Levels: Unspecified. Presumed high.
(3) Type of Task/Skill Required: Instrument Flight Procedures
(4) Task Difficulty: Medium-high

i. Stage of Training: Transition from Single-Engine to Twin-Engine Fixed Wing aircraft

j. Trainee Sophistication: Medium (had single-engine flight experience)

k. Incorporation of Device into P.O.I.: Lock-step

l. User Acceptance or Attitude:
(1) Instructors: not discussed
(2) Students: not discussed

m. Use of Instructional Features:
(1) Intensity: not discussed
(2) Features used: not discussed

9. Abstract:

a. Study Synopsis: When training requirements change, the simulation training devices in use and their associated training programs must be reevaluated to assure their continued effectiveness. A fundamental change made in the U.S. Army Aviation School in FY 67, shifting to use of a twin-engine plane as the principal instrument training aircraft, afforded the opportunity to test the effectiveness of a new training device in the course of revising then-existing instrument training programs.

The present study examines the substitution of the GAT-2 instrument flight simulator in place of the lower-fidelity 2B12A device then in use. Experimental subjects received training on the GAT-2; controls received no simulation training whatsoever. As measured by early attrition rates and by checkflight

1. Authors: Caro, Paul W., Isley, Robert N., & Jolley, Oran B.

2. Title: Research on Synthetic Training: Device Evaluation and Training Program Development - (Study One).

3. Source: Human Resources Research Organization Technical Report 73-20, September 1973; pp. 1-22.

4. Topic Keywords: Instrument Flight Simulator ; Transition ; Transfer .

5. Short Summary: The substitution of a new synthetic training device to parallel changes in equipment (e.g., single-engine to twin-engine aircraft), can be made in existing training program with acceptable effectiveness. But the modification of the training program is indicated in order to exploit the advantages of the new device.

6. Devices: GAT-2 , off-the-shelf Fixed Wing Simulator for instrument flight procedure training.

7. Institutions:

   a. Sponsor: Office of the Chief of Research and Development, Department of the Army

   b. Performing Organization:
   Human Resources Research Organization Division No.6 (Aviation), Fort Rucker, AL 36362

8. Type of Article: Experiment.

   a. Number of Groups: Two Group Post Test

   b. Description of Groups:
   (1) Subjects: 24 Trainees, Officer/Warrant Officer Fixed Wing Aviator Course, with mean prior flight experience 6.8 hours
   (2) Controls: 16 same with mean prior flight experience 10.6 hours (augmented to 35 controls after attrition of original 16)

   c. Tests or Trials/Timing: Post-test

   d. Number of Different Types of Measures: 2

   e. Description of Measurements and Ratings:
   (1) Performance Measures: Two instrument-phase checkrides with scored photographic record; trainee flight records; attrition rate in early phases; number of flight hours to criterion

reduction in number of eliminations due to flying deficiency resulted from device training. Device-trained subjects also excelled in other performance measures during early stages of training. However, after the first solo flight on real aircraft, no significant differences were observed between device-trained subjects and control groups, on any of the flight performance measures used in this study.

The difference in elimination rates took place mostly in the early (Pre-Solo) phase of flight training. The device assisted in learning of gross motor skills; these are relatively important in early stages of training, but at later stages these skills decline in importance relative to more specific skills.

Experimental subjects reached a Pre-Solo checkride level of proficiency somewhat more quickly than control subjects. This suggests that advancement of trainees according to proficiency (rather than according to experience) could lead to significant savings in a flight program.

Experimental subjects were subdivided into two groups, of which one received a mean of 3.17 hours on the device, the other a mean of 7.13 hours; however, no significant differences in performance measures emerged between these two groups. This indicated a practical value in investigating the effects of further reductions of device training time to find an optimum.

b. Results: Simulator device training reduced the rate of eliminations of candidates due to Flight Deficiency from 30% to 10%. Also, device-trained subjects acquired skills necessary for solo flight with significantly less in-flight training than controls.

c. Authors' Conclusions: "... the use of a helicopter contact flight training device of the type used in this study could result in a significant reduction in elimination rates from subsequent helicopter flight training and in significant improvements in trainee performance early in such training."

(4) Checkride grades

f. Experimental Setting/Training Context: Institutional; hands-on

g. Statistical Methods: ANOVA

h. Variables Being Manipulated:
(1) Training Devices: Captive Helicopter: Whirlymite Helicopter Trainer, Model DHT-1, one-man helicopter attached to Del Mar Ground Effect Machine, operating in real-world, out-of-door environment
(2) Fidelity Levels:
(a) Physical: high
(b) Functional: medium
(3) Type of Task/Skill Required: operations; psychomotor; whole-task
(4) Task Difficulty: high

i. Stage of Training: introduction; familiarization; transition

j. Trainee Sophistication: intermediate

k. Incorporation of Device into P.O.I.: lock-step

l. User Acceptance or Attitude:
(1) Instructors: not discussed
(2) Students: not discussed

m. Use of Instructional Features:
(1) Intensity: not specified
(2) Features used: not specified

9. Abstract:

a. Study Synopsis: Although trainees with fixed-wing experience are rarely eliminated from helicopter flight training, failure rates are high among helicopter flight trainees in general. A helicopter flight simulator providing contact aeronautical experience gives the novice the opportunity to practice contact flight maneuvers which, at his proficiency level, would be unsafe in an aircraft. The device selected for this study differed from conventional flight training devices in operating in a real-world, out-of-door environment, providing visual, auditory, and proprioceptive stimuli associated with hovering flight in a free-flying helicopter.

A statistically significant (p=.006) two-thirds

1. Authors: Caro, Paul, W. & Isley, Robert

2. Title: Helicopter Trainee Performance Following Synthetic Flight Training.

3. Source: Journal of the American Helicopter Society, Vol. 11, No. 3, July 1966 pp. 38-44; Human Resources Research Organization Professional Paper 7-66, November 1966.

4. Topic Keywords: Contact Aeronautical Experience ; Synthetic Flight Training .

5. Short Summary: The use of a Synthetic helicopter contact flight training device was shown to be associated with a significant reduction in elimination rates from subsequent helicopter flight training and in significant improvements in trainee performance in the early stages of training.

6. Devices: Captive Helicopter; Whirlymite Helicopter Trainer, Model DHT-1, one-man helicopter attached to Del Mar Ground Effect Machine, operating in real-world, out-of-door environment.

7. Institutions:

   a. Sponsor: Department of the Army

   b. Performing Organization:
   George Washington University , Human Resources Research Office, Division 6, Fort Rucker, AL 36362

8. Type of Article: Experiment.

   a. Number of Groups: 2

   b. Description of Groups:
      (1) Subjects: 66 male enlisted volunteers, Warrant Officer Candidates, Rotary Wing Aviator Course
      (2) Controls: 66 same

   c. Tests or Trials/Timing: Post-test and in-process grades

   d. Number of Different Types of Measures: 4

   e. Description of Measurements and Ratings:
      (1) Rate of elimination from training
      (2) Flight time to checkride
      (3) Daily grades

1. Authors: Cicchinelli, Louis F., & Harmon, Kenneth R.

2. Title: Training and Cost Effectiveness of Two Avionics Maintenance Training Simulators

3. Source: Proceedings, 23rd Annual Conference of the Military Testing Association, Arlington, VA: October 25-30, 1981; pp. 269-278

4. Topic Keywords: Maintenance Training ; Maintenance Troubleshooting ; Simulation ; Fidelity ; Low fidelity .

5. Short Summary: Two studies compared two simulators of differing fidelity with actual equipment used in maintenance training. The simulators were found to be as effective as the actual equipment and far less expensive.

6. Devices:

a. 6883 Convertor/ Flight Control System Maintenance Test Station for the F-111

b. Three Dimensional 6883 Convertor/ Flight Control System Simulator

c. Three Dimensional 6883 C-FC Simulator including Patch-panel Part-task Trainer

d. Two Dimensional 6883 Simulator and Part-task Trainer

7. Institutions:

a. Sponsor: Air Force Human Resources Laboratory, Lowry AFB, CO.

b. Performing Organization: Denver Research Institute, Denver, CO

8. Type of Article: Experiment.

a. Number of Groups:
(1) Study One: 4
(2) Study Two: 4

b. Description of Groups:
(1) Study One
(a) 28 F-111 avionics maintenance trainees, simulator trained, simulator tested
(b) 28 same, simulator trained, actual equipment tested

(c) 29 same, actual equipment trained, simulator tested
(d) 30 same, actual equipment trained, actual equipment tested
(2) Study Two
(a) 34 F-111 avionics maintenance trainees, 2-D simulator trained
(b) 35 same, 3-D simulator trained
(c) 13 same, 3-D expanded simulator trained
(d) 34 same, actual equipment trained
(Note: test modes not specified for Study Two results)

c. Tests or trials/timing:
(1) Study One: 2 post-tests
(2) Study Two: Pre-assessment abilities tests; 3 performance post-tests

d. Number of different types of measures: 3 for hands-on trouble-shooting post-test; 2 additional for other tests

e. Description of Measurements and ratings:
(1) Hands-on performance test: total score
(2) Hands-on performance test: time to completion
(3) Hands-on performance test: degree of assistance required for completion
(4) Projected Job Proficiency Test: multiple answer
(5) (Study Two only) Paper and pencil test

f. Experimental setting/training context: Institutional, hands-on

g. Statistical methods: One way ANOVA

h. Variables being manipulated:
(1) Training Device: as above, section 6
(2) Fidelity Levels:

	Physical	Functional
Actual Equipment	High	High
3-D Simulator	Med-high	(High)
2-D Simulator	Med-low	(High) (assumed)

(3) Type of task/skill required: maintenance troubleshooting;, cognitive, psychomotor, procedural, part-task & whole-task
(4) Task Difficulty: Medium-high

i. Stage of Training: not specified; assumed introduction, familiarization, transition

j. Trainee sophistication: not specified; assumed intermediate

k. Incorporation of Device into P.O.I.: not specified; presumably lock-step

l. User acceptance or attitude: not discussed

m. Use of instructional features:
(1) Intensity: presumably intensive
(2) Features used: not specified

9. Abstract:

a. Study Synopsis: Two experiments were conducted to compare the effectiveness of two simulators of differing fidelity with the actual equipment in the training of maintenance test and troublshooting tasks. In Study One, the 6883 Convertor/Flight Control System maintenance test station for the F-111 was compared with a 3-dimensional simulator; in Study Two, these two devices were compared with the third device, a two-dimensional simulator (a fourth device was an expansion of the 3-D simulator). Subjects were F-111 avionics maintenance trainees, 115 in Study One and 119 in Study Two. Measurements in Study One were of performance in a hands-on post-test and in a multiple-answer Projected Job Proficiency Test. In Study Two, pre-assessment ability tests were given, and a third paper-and-pencil post-test was added.

Cost analyses of the actual equipment and the 3-dimensional simulator were also conducted.

b. Results:
(1) Key Data:

	Training Mode			(Study Two)	
	AET	2-D	3-D	3-D/PPT	Total
Hands-on Score					
x	21.50	22.53	21.74	21.77	21.91
N	34	34	35	13	116
PJPT Score					
x	20.77	20.58	20.85	21.23	20.79
N	35	36	35	13	119
P&PTS Score					
x	19.29	19.47	17.52	21.23	19.11
N	31	36	29	13	109

(2) Verbal Description: In Study One, simulator-trained and AET-trained students did not differ appreciably with respect to overall trouble-shooting test performance. A very slight

advantage in test accuracy was found for actual- as opposed to simulator-trained students tested on the actual equipment, but this finding was not mirrored using completion time as a measure. The Projected Job Proficiency Test, a multiple answer performance test, also indicated no significant differences among groups as a function of training mode.

In Study Two, a preliminary analysis indicated that there were no significant differences in the preassessment scores among the four experimental groups.

Performance post-test results from Study Two are shown in the table above. When all four levels of training were submitted to one-way analyses of variance, no significant differences among means were found for any of the three measures. It should be stressed that this analysis collapsed student groups across testing modes and that being trained and tested on different systems may result in confounding of performance measures due to unfamiliarity with the equipment used for testing. In fact, an analysis involving only those groups of students who were trained and tested on the same equipment revealed no significant differences in performance on any of the three measures. Study Two analyses are preliminary, and a final analysis will present data required to compare performance as a function of training equipment, when only the actual equipment is used for testing.

Cost analyses indicated that the 3-D simulator is at most half as expensive as the actual equipment. Cost analysis of the 2-D simultor was not complete at the time of this preliminary report.

c. Authors' Conclusions: Based on the results of Study One and the preliminary analysis of Study Two data, it can be concluded that students trained on the 3-D and 2-D simulators performed as well as students trained on actual equipment.

The generalizability of the findings presented here is, of course, limited. While every effort was made to adapt experimental design principles to this natural setting, it was not possible to rely on many of the premises of basic learning theory. Until parameters such as course content, training method, and duration of training, all known to affect learning, are subject

to more careful control, a rigorous cost effectiveness analysis of simulation training is not possible.

1. Authors: Cox, John A., Wood, Robert O. Jr., Boren, Lynn M., & Thorne, H. Walter.

2. Title: Functional and Appearance Fidelity of Training Devices for Fixed-Procedures Tasks

3. Source: Human Resources Research Organization Technical Report 65-4, June 1965.

4. Topic Keywords: Fidelity ; Fixed-Procedure Task ; Low Fidelity ; Functional Fidelity .

5. Short Summary: Twelve training devices of varying levels of fidelity were compared on the training of a procedural task. The experiment found no significant differences in effectiveness due to the fidelity level of the training device, as measured by transfer to the highest fidelity training device during a performance test.

6. Devices:

a. High Fidelity Simulator "Hot Panel": Tactical Equipment

b. High Fidelity Simulator "Cold Panel": Tactical Equipment

c. High Fidelity Simulator "Frozen Panel": Tactical Equipment

d. Cardboard Panel -- Entire device fabricated with cardboard, painted to resemble device a.

e. Photographic Panel -- a full-size B&W photograph of device a.

f. Drawing Panel -- a full-size B&W line drawing of device a.

g. High Fidelity Housing -- device "b." with replica of device "a." housing

h. Box Housin -- device "b." with plywood housing

i. Frame Housing -- device "b." with wooden frame housing

j. Full-Size Panel -- device "f." but with larger lettering

k. Half-Size Panel -- half-size reproduction of device "j."

l. Small Panel -- one-nineteenth size reproduction of device "j."

7. Institutions:

a. Sponsor: Office, Chief of Research and Development, Department of the Army , Washington, DC 20310.

b. Performing Organization: Human Resources Research Office, George Washington University , Alexandria, VA 22314.

8. Type of Article: Experiment.

a. Number of Groups: 16

b. Description of Groups:
(1) For Studies I-IV, all subjects were male Army trainees who were receiving training in another specialty than the one being studied; to eliminate confounds due to prior knowledge of equipment, GT scores were as closely matched as possible among all groups.
(a) Study One, Functional Fidelity: 3 groups, 20 each
(b) Study Two, 2-dimensional v.s. 3-dimensional: 4 groups, 20 each
(c) Study Three, Reduced Housing, 3 groups, 15 each
(d) Study Four, 2-D v.s. 3-D/Reduced Housing, 3 groups, 15 each
(e) Study Five, Size, 4 groups, 15 each
(2) Study VI subjects were actually in training for the specialty including this equipment ("Field" study)
(a) 35 controls
(b) 36 subjects

c. Tests of Trials/Timing: 1 post-test (run-through of procedural sequence)

d. Number of Different Types of Measures: 2

e. Description of Measurements and Ratings:
(1) Number of correct actions taken in 92-step procedure
(2) Time to complete task

f. Experimental Setting/Training Context:
(1) Studies I-V: Laboratory, hands-on
(2) Study VI ("Field"): Institutional, hands-on

g. Statistical Methods: Analysis of covariance

h. Variables being manipulated:
(1) Training Devices: as above, section 6
(2) Fidelity Levels: varied from low to high in both physical and functional dimensions
(3) Type of Task/skill required: procedural, perceptual, cognitive (varying degrees), psychomotor (varying degrees)
(4) Task Difficulty: Medium-low

i. Stage of Training:
(1) Studies I-V: procedural, familiarization, skill
(2) Study VI: transition, skill

j. Trainee Sophistication:
(1) Studies I-V: novice
(2) Study VI: intermediate

k. Incorporation of device into P.O.I.: lock-step

l. User Acceptance or Attitude (Study VI)
(1) Instructors: generally cooperative, but doubtful about low-fidelity devices
(2) Students: not discussed

m. User of Instructional Features:
(1) Intensity: intensive
(2) Features used: not specified

9. Abstract:

a. Study Synopsis: The purpose of this study was to evaluate the training effectiveness of 12 simulators which ranged in fidelity from an instrument panel to high physical and functional fidelity down to a line drawing of the panel which measured only 5"x7". The task chosen for study was a long (92-step) but essentially straightforward, nonbranching procedural sequence of low difficulty. Subjects were trained through the sequence on the various devices, so that in the course of five laboratory studies all devices were used by at least one group once. All subjects were subsequently tested on the high-fidelity simulator which had served as a trainer for some of the groups. Subjects were matched in groups according to GT score as closely as possible. Analyses of covarience were run on data to assure that aptitude of subjects was not a determining variable. In studies I-V, the subjects were purely experimental, being enlisted in the Army under another, somewhat similar specialty; in Study

VI, called by the authors the "Field Study," subjects were actually undergoing training for the task under study. After Study VI, participating instructors were interviewed to assess their attitudes toward the devices.

b. Results:

(1) Key Data:

Proficiency Scores of Trainees
By Training Group: Study II

	Hot Panel (N=20)	Cold Panel (N=20)	Photo Panel (N=20)	Drawn Panel (N-20)
Mean	85.8	82.4	83.7	82.0
Median	89.5	83.5	84.5	86.0

Proficiency Scores of Trainees by Method
and Training Group: Study V

	Method One		Method Two	
	Full-Size Panel	Half-Size Panel	Half-Size Panel	Small Panel
Mean	81.9	85.1	83.7	82.4
Median	84.0	86.0	83.0	84.0
Std. Dev.	7.5	5.1	5.5	6.9

(2) Verbal Description: No significant differences appeared among any of the groups trained on the various devices, in the laboratory or in the field. Results from Studies I and V are shown above. Remarkably, the small line drawing proved as effective in training as the full-size panel.

c. Authors' Conclusions: When men are being trained to perform a procedure and a training device is to be used as a method of training them, the requirements for functional fidelity in the device are quite low. Limiting factors to be considered: (1) this applies only to procedural tasks; (2) the training device does not train men by itself; the whole training process produces the effect. Orientation, techniques of instructors, and psychological atmosphere all affect acquisition of skill; (3) some variations occur when verbal signals replace visual and auditory signals; while these variations produced no significant differences in the present study, changes in the training environment might produce differences in the effectiveness of devices at different levels of functional fidelity.

The size study extends the implications of the other studies. It appears that small pictures or drawings can be used as training devices, each trainee having his own device from which to study and perform. The limitation on size reduction seems to be only that the trainee must be able to see the elements on the device clearly and to read any lettering.

The added work load on the instructors when using lower fidelity devices did not hamper training to any measurable extent. The field study data showed that instructors were able to perform equally well under high and low fidelity conditions, despite the lack of confidence expressed by some instructors in the low fidelity devices.

1. Authors: Crawford, Alice, Hurlock, Richard, Padillo, Robert, & Sassano, Anthony

2. Title: Low Cost Part-Task Training Using Interactive Computer Graphics for Simulation of Operational Equipment

3. Source: Defense Technical Information Center Technical Report NPRDC TR TQ 76-46, 1976.

4. Topic Keywords: Computer-Aided Instruction ; Interactive Graphics ; Computer Graphics ; Individualized Training ; Part-Task Training ; Computer Based Training ; Learner Control .

5. Short Summary: A computer-based interactive simulator with program versatility is a cost-effective low fidelity alternative to higher fidelity devices for certain tasks in the less advanced phases of training.

6. Devices: Computer-Based Simulator; High-Fidelity Performance Testing Device

7. Institutions:

   a. Sponsor:
   Navy Personnel Research & Development Center, San Diego, CA

   b. Performing Organization: same

8. Type of Article: Experiment.

   a. Number of groups: 2

   b. Description of Groups:
      (1) Subjects: 22 male co-pilot trainees
      (2) Controls: same

   c. Tests or Trials/Timing: Post-test

   d. Number of Different Types of Measures: 1

   e. Description of Measurements and Ratings: two post-tests, each requiring performance of two tasks, consisting of 6- 10 sequential responses, scored by instructors

   f. Experimental Setting, Training Context:

   g. Statistical Methods: F test

   h. Variables Being Manipulated:

(1) Type of Training Device: PLATO IV Interactive Computer Training System, with 8 1/2" square plasma display panel and 64-character keyboard plus touch panels with 256 programmable areas for entering data; testing of subjects and controls was done on high-fidelity simulator which was standard training device.
(2) Fidelity Levels: Low to Medium
(3) Type of Task: Procedural and simple perceptual motor activities
(4) Task Difficulty: Unspecified, presumably only moderate

i. Stage of Training: Copilot training, familiarization procedures

j. Trainee Sophistication: not specified, presumably novice or intermediate

k. Incorporation of Device into P.O.I.: lock-step

l. User acceptance or Attitude:
(1) Instructors: not specified
(2) Students: Good. After testing, most trainees returned to practice on computer-based simulator

m. Use of Instructional Features:
(1) Intensity: intensive
(2) Features used: not specified

9. Abstract:

a. Study Synopsis: Computer-Based interactive simulation of equipment using a versatile, variable-programmable computer graphics display (the PLATO IV) has the advantages, over high-fidelity, system-specific simulators, of (1) permitting lesson materials to be programmed with a chosen lesson strategy; and (2) offering more training on different kinds of equipment simply by changing computer programs.

Furthermore, within the context of learning specific tasks, computer-based simulation (regardless of type of display) can provide immediate and automatic feedback and monitoring of student behavior.

The purpose of the present research was to determine the effectiveness of computer-based graphic simulation of a particular piece of high-fidelity training equipment, in the teaching of certain procedural and simple perceptual motor skills, as part of a co-pilot

training program. An additional purpose was to evaluate the cost-effectiveness of the specific computer system used, the PLATO IV developed at the University of Illinois; and a cost comparison with conventional training, favorable to the PLATO IV, is included in this report.

In this study, 3 hours of Computer-Based Training (CBT) was given to the experimental subjects, versus 3 hours of conventional workbook study assigned to the controls. Subsequently, on a high fidelity performance testing device (PT), the experimental subjects performed significantly better than controls on an initial test, and maintained an equal superiority over the workbook trained students on a second test, even after both groups had received an hour's practice on the PT, although both groups improved. Even more startling, the performance of the CBT students on the first test (before practice on the PT) was superior to the controls' performance on the second test (after an hour's practice on the PT).

Note: Instructors tested on the PT performed far better than either training group, showing that all student learning was still far from asymptotic.

Although training time on the high fidelity simulator (PT) was not equal to training time on the computer-based simulator (1 hr. versus 3 hrs.), the authors contend the computer-based simulator is a cost-effective alternative to the higher-fidelity device at certain tasks in the less advanced phases of training.

b. Results: Comparison of Group Performance on Tests 1 and 2

	Test 1		Test 2	
	Time (Min.)	No. Tasks Completed	Time (Min.)	No. Tasks Completed
Computer Based	2.85	1.68	1.88	2.00
Workbook	4.44	1.18	3.32	1.73

Students trained on the Computer-Based Simulator (CBT) completed significantly more problems and took less time on two posttests than non-CBT controls who received only standard workbook instruction. Moreover, after an hour's acquaintanceship with the high-fidelity performance test (PT), the CBT-trained students maintained their superiority.

c. Authors' Conclusions: Computer-Based Simulation provided training transferable to actual equipment, without degradation due to absence of hands-on practice with actual equipment. On certain specific procedural and simple perceptual motor skills, practice with the high- fidelity simulator could be eliminated for those receiving Computer-Based Simulation. Considerable savings might be realized by replacing some elements of the conventional program with Computer-Based Training.

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1. Authors: Cream, Bertram W., Eggemeier, F. Thomas, & Klein, Gary A.

2. Title: A Strategy for the Development of Training Devices

3. Source: AFHRL-TR-78-37, August 1978; Human Factors, 1978, 20(2), 145-158

4. Topic Keywords: Flight Simulation ; Task Analysis ; Training Requirements Analysis ; Instructional Systems Development .

5. Short Summary: A methodology for training device design is described. The results of an empirical study evaluating a device designed by this methodology suggest that this methodology produced an effective and well- accepted device.

6. Devices: AC-130E Gunship Trainer

7. Institutions:

a. Sponsor: HQ Air Force Human Resources Laboratory (AFSC), Brooks AFB, TX 78235

b. Performing Organization: Advanced Systems Division, Air Force Human Resources Laboratory, Wright-Patterson AFB, OH 45433

8. Experiment:

a. Number of Groups: 2

b. Description of Groups:
(1) Subjects: 17 AC-130E Gunship students (in three position-designated subgroups, one subgroup per position)
(2) Controls: 27 same (in 3 subgroups)

c. Tests or Trials/Timing: Post-tests (missions)

d. Number of Different Types of Measures: 1

e. Description of Measurements and Ratings: 4-point Instructor grade

f. Experimental Setting/Training Context: institutional, hands-on

g. Statistical Methods: Single-factor ANOVA; Duncan New Multiple Range Test

h. Variables Being Manipulated:
(1) Training Devices: AC-130E Gunship Trainer
(2) Fidelity Levels: not specified
(3) Type of Task/Skill Required: operations, cognitive, psychomotor, perceptual, procedural, whole-task
(4) Task Difficulty: Medium-high to High

i. Stage of Training: introduction; skill

j. Trainee Sophistication: intermediate

k. Incorporation of Device into P.O.I.: not specified

l. User Acceptance or Attitude:
(1) Instructors: positive as measured by questionnaire
(2) Students: very positive as measured by questionnaire

9. Abstract:

a. Study Synopsis: This study comprises descriptions both of a training device design methodology, and of an empirical evaluation of a trainer which was designed according to that methodology.

The methodology assumes that a simulation training device has been selected as a medium. The roles of three groups--users, training psychologists, and simulation engineers--are described whereby the psychologist serves as interface between user and engineer. Together with the user, psychologists put together information on the training task which becomes the input to the engineer. "Users...must significantly influence decisions about fidelity and capability.... The psychologist and engineer can provide the user with the information necessary to make balanced judgements regarding fidelity, cost, and training.... No rigorous decision-making procedures have been developed here. The factors in the cost capability tradeoff are not easily quantified."

The heart of the method is the ranking of each feature--especially the task and sub-tasks to be trained-- along three dimensions: criticality, frequency of performance, and difficulty of performance, with criticality the most heavily weighted. These rankings serve as flexible guides (rather than rigid prescriptions) to user and psychologist as to what features to include and the fidelity level of each.

Performance measures and crew coordination are also discussed. Practical examples substantiate many of the principles which are set forth.

The trainer developed through this methodology which was evaluated by empirical study was for an AC-130E gunship. The device trained a crew on four positions. Training for three of the positions was evaluated in this experiment. Training for control subjects included classroom instruction and airborne training. Training for experimental subjects consisted of classroom instruction, training with the new device, and aircraft training. There were 9 control subjects at each position; experimental subjects numbered 6, 6, and 5 at the three positions. Performances of all subjects in ten airborne missions subsequent to ground-based training were graded by instructors on a 4-point scale, where "0" represented inadequate, "2" represented qualified, and "3" represented completely qualified.

b. Results:

(1) Key Data:Number of Flying Training Missions to Consistent Criterion for Each Subject at Each of Three Positions:

POSITION 1		POSITION 2		POSITION 3	
Experi-mental	Control	Experi-mental	Control	Experi-mental	Control
2	5	4	4	2	4
2	7	4	6	3	5
3	7	5	6	5	5
3	9	5	7	5	5
4	9	5	7	7	6
6	9	7	7		7
	10		8		7
	10		8		7
	10		9		8
X=3.3	X=8.4	X=5	X=6.8	X=4.4	X=6

(2) Verbal Description: The Duncan New Multiple Range Test indicated that the Position 1 experimental group differed significantly from its control ($p<0.01$), and that the Position 2 and 3 experimental groups differed from their controls ($p<0.05$). Experimental groups reached consistent criterion with less airborne training time than did control groups at each of the three positions.

Also, at each position, a greater percentage of

subjects trained with the device received "completely qualified" ratings than did control subjects. This proficiency effect was most marked in the Position 1 group and represented only a consistent trend in the other two groups.

Also, a questionnaire indicated high acceptance of the device among all users.

c. Authors' Conclusions: "It can be concluded that design of a training device according to the strategy (described) did produce an effective device which was well accepted by the users."

1. Author: Crosby, John V.

2. Title: Cognitive Pretraining: An Aid in the Transition from Instrument to Composite Flying

3. Source: AFHRL-TR-77-62, October 1977

4. Topic Keywords: Cognitive Pretraining ; Flight Training ; Schema ; Stimulus-Response .

5. Short Summary: Cognitive pretraining appears to be effective in preparing student pilots to make the transition from basic instrument flight simulation to real aircraft visual flight.

6. Devices: Photographs

7. Institutions:

   a. Sponsor: HQ Air Force Human Resources Laboratory , Brooks AFB, TX 78235

   b. Performing Organization: Department of Psychology, Arizona State University

8. Type of Article: Experiment.

   a. Number of Groups: 2

   b. Description of Groups:
      (1) Subjects: 12 Air Force undergraduate pilot training students
      (2) Controls: 12 same

   c. Tests or Trials/Timing: Post-test

   d. Number of Different Types of Measures: 2

   e. Description of Measurements and Ratings:
      (1) Laboratory measurement of perceptual accuracy of view
      (2) Flight maneuver simulated checkride, instructor- rated on scale of 1 - 12

   f. Experimental Setting/Training Context: Institutional; hands-on

   g. Statistical Methods: Multivariate ANOVA

   h. Variables Being Manipulated:
      (1) Training Devices: photographs
      (2) Fidelity Levels:

(a) Physical: Medium-low
(b) Functional: Low
(3) Type of Task/Skill Required: operations; perceptual
(4) Task Difficulty: Medium

i. Stage of Training: transition; post-basic instrument; pre-flight

j. Trainee Sophistication: novice with less than 50 hours flying time

k. Incorporation of Device into P.O.I.: self-paced

l. User Acceptance or Attitude:
(1) Instructors: not discussed
(2) Students: not discussed

m. Use of Instructional Features:
(1) Intensity: not discussed
(2) Features used: not specified

9. Abstract:

a. Study Synopsis: The USAF Undergraduate Pilot Training Program at Williams AFB, AZ, is designed to train students to fly high-performance jet aircraft. Central to the training philosophy is the concept that students acquire and develop good judgement skills, showing adaptability and flexibility of performance, rather than fixed stimulus-response connections. In line with this concept, an experiment was conducted using trainees to examine the benefits of providing students with cognitive pretraining of visual flight situations following ground-based simulated instrument flight training and prior to the actual flying contact phase of training. This cognitive pretraining, it was hypothesized, would assist students in the usually difficult transition from basic instrument flying to the situation where 80% of the information is obtained from non-instrument sources.

A group of 12 subjects was provided with the cognitive pretraining prior to flight training, and the group's performance on (1) laboratory tests of perceptual accuracy of view from cockpit, and (2) a high-fidelity simulator test on flight maneuvers, was compared with the performance of a 12-member control group who received no cognitive pretraining. The cognitive pretraining materials consisted partly of photographic representations of the cockpit, showing visual orientation references that would be used in visual

flight (these photographs might be considerd to be low fidelity training devices).

The performance of the experimental group was significantly superior to the control group's, and in the cognitive laboratory test portion of testing was equal and in one parameter even superior to that of a group of 12 experienced Instructor Pilots who were used as a further control.

The experiment appeared to demonstrate the value of cognitive pretraining in the development of flexible and adaptive skills in flight training. The concept of schemata (for which the author proposed Evans' provisional definition "a schema is a characteristic of some population of objects. It is a set of rules which would serve as instructions for producing, in essential aspects, a population prototype and object typical of the population....") is helpful in examining this training phenomenon.

b. Results: Subjects who were given cognitive pretraining performed better than controls, both on medium-fidelity laboratory trials of visual pitch and bank discrimination for cockpit, and in flight maneuvers executed in a high- fidelity simulation testing device.

c. Author's Conclusions: Cognitive pretraining appears to offer a sound and economical approach to many aspects of flying training research. The concept of a schema places less emphasis on fixed stimulus-response chains and presumably more emphasis on the development of flexible and adaptive skills.

1. Authors: Crosby, John, Pohlmann, Lawrence, Leshowitz, Barry, & Waag, Wayne

2. Title: Evaluation of a Low Fidelity Simulator (LFS) for Instrument Training

3. Source: Technical Report, AFHRL-TR-78-22, July 1978

4. Topic Keywords: Transfer of Training ; Temporal Duration of Effect ; Low Fidelity .

5. Short Summary: Groups receiving "Low fidelity simulator pretraining" showed positive transfer early in pilot training. After one month of academic and higher fidelity simulator training, however, the pretraining showed no effect.

6. Devices: Low Fidelity Computer Monitored Instrument Flight Simulator

7. Institutions:

   a. Sponsor: HQ Air Force Human Resources Laboratory , Brooks AFB, TX 78235

   b. Performing Organization: Arizona State University/ Flying Training Division, Williams AFB, AZ 85224

8. Type of Article: Experiment.

   a. Number of Groups: 2

   b. Description of Groups:
      (1) Subjects: 7 Undergraduate Pilot Trainees, sex unspecified
      (2) Controls: 7 same

   c. Tests or Trials/Timing: Pretest simulator sortie, post- test simulator sortie, post-test contact flight evaluation

   d. Number of Different Types of Measures: 3

   e. Description of Measurements and Ratings:
      (1) Performance Measures: Evaluation sortie in Advanced Simulator for Pilot Training (ASPT) before and after normal T-4 instrument training; mean trials to criterion for T-4 instrument training; mean trials to criterion for subsequent basic real aircraft contact training
      (2) Supervisor Ratings: Not discussed

f. Experimental Setting/Training Context: Undergraduate Pilot Training Program

g. Statistical Methods: Not specified

h. Variables Being Manipulated:
(1) Training Device: Low-Fidelity Computer-Monitored Instrument Flight Simulator: Joystick mounted to straight-back chair, responds to x-y pilot input, simulates pitch and roll controls; adjacent lever simulates throttle. Abbreviated instrument panel.
(2) Fidelity Level: Low
(3) Type of Task/Skill Required: Basic Instrument Flight Maneuvers
(4) Task Difficulty: not evaluated

i. Stage of Training: Pre-Flight, Pre-High-Fidelity Simulator

j. Trainee Sophistication: Moderate (both groups had similar light aircraft flying experience; no subjects had jet aircraft flying experience)

k. Incorporation of Device into P.O.I.: Not discussed

l. User Acceptance or Attitude: Not discussed

m. Use of Instructional Features:
(1) Intensity: Not specified
(2) Features used: Not specified

9. Abstract:

a. Study Synopsis: An inexpensive Low Fidelity Simulator (LFS) was developed and used to appraise the transfer of simulator training to (1) more advanced simulator training, and (2) aircraft. The relevance of the LFS to real flying experience was confirmed by a preliminary study.

Two groups of 7 trainees each were tested on a full-mission simulating device before beginning normal basic academic and basic (T-4) instrument training. They were again tested on the sortie after a month of academic and basic instrument training and before contact flight training. The experimental group's training differed from the control in receiving 10 hours LFS basic instrument maneuver flying instruction prior to the first evaluation sortie and other, subsequent, instruction. The control groups had no LFS training at any time. While the experimental group

performed significantly superior to the control groups on the first evaluation sortie (the control group having received no training whatsoever at this point), it failed to excel on the second evaluation sortie a month later--after both groups had received approximately 35 hours medium-high-fidelity basic instrument (T-4) training and 28 hours academic procedures training; and the experimental group failed subsequently to excel the controls in contact flight.

In fact, among the experimental subjects, there was little difference between their performance on the first and second evaluation sorties. This suggests that the LFS training produced a "ceiling effect" on the subjects, such that subsequent higher fidelity training failed to improve their skills. Demand effects and/or ability of IP's during LFS training may have influenced this result as much as the simulator device itself.

Why simulator-trained students (subjects as well as controls) required a high number of trials to acquire skills in subsequent contact maneuvers is discussed in Section 9c, "Authors' Conclusions" below. The explanations for these shortcomings can be briefly summarized:

(1) The LFS does not faithfully reproduce the "feel of the aircraft"--a consequence of low fidelity!

(2) Inappropriate simulator-acquired skills may impede acquisition of contact maneuver skills.

b. Results: On the initial evaluation sortie before normal T-4 instrument and academic training, the Low Fidelity Simulator-trained group performed significantly better than controls across all maneuvers, and during T-4 training required fewer trials to criterion. After T-4 training, however, and likewise during T-37 real aircraft training, no differences were found between experimental and control groups.

c. Authors' Conclusions: Low-fidelity simulator training prior to onset of academic and higher-fidelity simulator instruction did not produce significant differences between experimental and control subjects during subsequent phases of training (basic instrument and basic contact). The evidence supports the explanation that the LFS training brought the experimental trainees early to a performance ceiling beyond which they were less likely to progress. The slowness of subjects to learn to execute maneuvers in

real aircraft can be ascribed to the lower level of stress and the lack of "feel of aircraft" in simulator. Furthermore, the "unlearning" of possible inappropriate skills "overlearned" in the simulator may impede contact maneuver performance.

Lastly, the initial high positive transfer of simulator learning in the èxperimental group may be due to the demand effects and/or instructional ability of the IP's. Transfer of training studies should investigate the instructive role of student, instructor, and T.D. as a system rather than focusing exclusively on the simulator.

post-test (transfer, on shipboard)

d. Number of Different Types of Measures: 17

e. Description of Measurements and Ratings:
  (1) Team Measures:
    (a) Average aircraft separation error
    (b) Time to complete Recovery of 11 aircraft
    (c) Communications noise level
  (2) Subteam Measures:
    (a) Aircraft position at one mile: average azimuth error
    (b) Aircraft position on one mile: average glideslope error
    (c) Communications efficiency
    (d) Communications noise level
  (3) Individual Measures:
    (a) Radar contact not announced to pilot
    (b) Use of primary approach frequency within 1/2 mile of ramp (inappropriate use)
    (c) Number of conflictions (inadequate spacing between aircraft)
    (d) Deviation from schedule ramp time for 1st aircraft
    (e) Marshall information broadcast: completeness and accuracy
    (f) EAT deviations beyond EAT plus or minus .25 minutes not acted upon
  (4) Controller Self Evaluations
  (5) Instructor Evaluations
  (6) LSO Evaluations of CATCC Performance
  (7) Pilot Evaluations

f. Experimental Setting/Training Context: Institutional, hands-on

g. Statistical Methods: not specified

h. Variables Being Manipulated:
  (1) Training Devices:
    (a) CATCC: Carrier Air Traffic Control Center, a multi-station team facility on shipboard
    (b) CATCC Trainer: a land-based simulator of the CATCC
    * Note: Chief variable was time on device.
  (2) Fidelity Levels:
    (a) Physical: medium-high
    (b) Functional: medium-high
  (3) Type of Task/Skill Required: aircraft piloting operations; cognitive; perceptual; procedural; whole-task

1. Authors: Finley, Dorothy L., Rheinlander, T. W., Thompson, E. A., & Sullivan, D. J.

2. Title: Training Effectiveness Evaluation of Naval Training Devices. Part I. A Study of the Effectiveness of a Carrier Air Traffic Control Center Training Device

3. Source: NAVTRAEQUIPCEN 70-C0258-1, August 1972; National Technical Information Service AD 751 556

4. Topic Keywords: Carrier Air Traffic Control ; Analytical Models ; Training Effectiveness ; Simulation .

5. Short Summary: Evaluation of a Carrier Air Traffic Control Center simulator finds it effective in training teams in the task of landing aircraft.

6. Devices:

a. CATCC: Carrier Air Traffic Control Center, a multi- station team facility on shipboard

b. CATCC Trainer: a land-based simulator of the CATCC

7. Institutions:

a. Sponsor: Naval Training Equipment Center, Orlando, FL 32813

b. Performing Organization: Bunker Ramo Electronic Systems Division, Westlake Village, CA

8. Type of Article: Experiment

a. Number of Groups: 2 (roughly)

b. Description of Groups:
(1) Subjects: "Ship One"--9 trainees with 1-3 weeks training on the simulator
(2) Subjects: "Ship Two"--6 trainees with 5 weeks training on simulator

Note: The teams representing "Ship One" and "Ship Two" were composed of various combinations of the trainees in each group, and also included at least one person who had received no simulator training, and another highly- experienced controller.

c. Tests or Trials/Timing: In-process trials;

provided by instructors can be used to identify problem areas and to identify the resistance which may be met to the proposed use of simulators in place of actual equipment.

survey of training equipment problem areas and new simulator requirements for maintenance courses.

b. Results:

(1) From the first questionnaire: most instructors, regardless of the type of equipment covered in their course or the level at which the course was conducted, answered the questionnaire in a similar fashion. In most courses actual equipment trainers were employed and instructors preferred it that way even though many complained about the reliability of the equipment. Many instructors expressed a willingness to use less expensive training devices and media if they were provided with them and if they were convinced of their effectiveness.

(2) From the second questionnaire: Few instructors registered complaints about the training equipment at their disposal. However, a substantial minority did report that they had problems with the reliability of their trainers. Of the 36 top candidate equipments for simulation, 19 were identified by Lowery AFB instructors known to be involved with or knowledgeable about simulation efforts related to the test bench. An additional 9 of the top 36 were identified by instructors at Keesler AFB, most of whom were involved with or knowledgeable about an on-going simulation effort at that base. Of the six high priority simulation candidates identified by Chanute AFB instructors, three of these pertained to flight simulators of the type for which simulator specifications were being developed.

c. Authors' Conclusions: With regard to use of new devices, and especially low fidelity simulators, instructors tend to be conservative in that they prefer to use proven instructional devices and techniques with which they are familiar. This suggests that instructors may be good information sources with respect to the effectiveness of training devices and techniques but that they normally would not be good sources of information about where and under what conditions state-of-the-art training devices might be employed. Instructors tend to recommend the use of simulators to the extent that they are familiar with simulators and how they can be effectively employed to teach maintenance on the type of equipment covered by their course.

With respect to instructor evaluation of training equipment in use at the time, information and opinions

1. Authors: Fink, C. Dennis, & Shriver, Edgar L.

2. Title: Maintenance Training Simulators at Air Force Technical Training Centers: Present and Potential Use

3. Source: AFHRL-TR-78-77, December 1978

4. Topic Keywords: Maintenance Training Simulation .

5. Short Summary: A study of the need for simulators in Air Force maintenance training through questionnaires administered to instructors, finds the questionnaire instrument of some usefulness, primarily limited to identifying problem areas calling for the intervention of simulation and training experts.

6. Devices: Many actual equipment devices are listed as prime targets for simulation.

7. Institutions:

a. Sponsor: HQ AFHRL Air Force Human Resources Laboratory (AFSC), Brooks AFB, TX 78235

b. Performing Organization: Kinton, Inc., 1500 North Beauregard Street, Suite 205, Alexandria, VA 22311

8. Type of Article: Survey

9. Abstract:

a. Study Synopsis: This study, employing questionnaires administered to 98 Air Force maintenance instructors as its instrument of evaluation, had two quite different but interdependent objectives: primarily, to identify the present and potential need for maintenance simulators in support of training conducted at Air Force Technical Training Center; secondarily, to investigate the usefulness of survey procedures for identifying training equipment simulation candidates--that is, to assess the value of the questionnaire instrument itself. A third and lesser objective was to obtain opinions about the use of low to medium cost-fidelity training devices. One hundred different courses were surveyed, including equipment in the following areas: electronic, electro-mechanical, precison/measuring, electrical/telecommunications, engines (aircraft), hydraulic, and miscellaneous others.

Two types of questionnaires were used: a survey of instructor opinions regarding use of low and medium cost/fidelity training devices and simulators, and a

develop a tendency for greater variability, and this carries over into the transfer task and also into post-evaluation retention performance.

The study results demonstrate that simulation fidelity can be degraded by using rigid coefficients in programmed flight equations and still be an effective condition for training. One can infer from this finding that high engineering fidelity is not a necessity.

Comparisons Between Average Performances of Experimental Group (Least Squares) Transfer Trials with Control Group (Flexible Data) on Comparable Trials

Parameter	Control Group(C)	Expermt. Group(E)	Ratio E/C	Prob.
Phase				
Altitude Error	208.00	541.00	2.60	.02*
Heading Error	17.50	25.20	1.44	.20
Climbing Turn				
Fore/Aft Stick Var.	2.50	5.90	2.36	.03*
Lateral Stick Var.	.37	.85	2.30	.03*
Altitude Error	201.00	176.00	.87	.45
Heading Error	21.10	29.00	1.37	.25
Level Turn				
Fore/Aft Stick Var.	2.60	2.50	.96	.45
Lateral Stick Var.	.43	.93	2.16	.05*

* Exceeds .05 Significance Level

(2) Verbal Description: During both transfer and retention testing, significant differences did not appear between controls and subjects trained in the "rigid airframe" condition. Between the controls and the subjects trained on the least-square condition, significant differences in system output did appear in altitude error only. However, data on pilot input showed that the least-square group had to work much harder (i.e., there was more stirring of the stick) to accomplish the same output result.

Statistical analysis of the pilot questionnaire was not performed due to sample size. However, no correlation in the questionnaire results was observed to suggest that the pilots had discriminated between the different levels of simulation fidelity.

c. Authors' Conclusions: The use of aerolastic equations simplified by rigid coefficients in flight trainer settings provides an effective training basis for subsequent transfer to high fidelity simulation.

Using least squares approximations to the flexible coefficients in the aerodynamic equations during training on the simulator is of doubtful value. It seems that during training, the least squares pilots

At all stages of training and testing, objective measuremens of error and deviation were made both of pilot input (manipulation of controls) and system ouput (simulated aircraft flightpath), in several parameters. Subjective evaluations of the device training were also made by subjects and controls via questionnaire.

b. Results:

(1) Key Data:

Comparisons Between Average Performances of Experimental Group (Rapid Data) Transfer Trials with Control Group (Flexible Data) on Comparable Trials

Phase Parameter	Control Group(C)	Expermt. Group(E)	Ratio E/C	Prob.
Altitude Error	208.00	213.00	1.02	.50
Heading Error	17.50	16.80	.96	.45
Climbing Turn				
Fore/Aft Stick Var.	2.50	3.10	1.24	.30
Lateral Stick Var.	.37	.37	1.00	.50
Altitude Error	201.00	180.00	.89	.45
Heading Error	21.10	22.20	1.05	.45
Level Turn				
Fore/Aft Stick Var.	2.60	4.00	1.54	.20
Lateral Stick Var.	.43	.50	1.16	.35

m. Use of Instructional Features
(1) Intensity: intensive
(2) Features used: Number/Quality of Responses; others not specified

9. Abstract:

a. Study Synopsis: This study continued an extensive program of research on varying functional fidelity in a jet flight simulator, using the Universal Digital Operational Flight Trainer Tool, a high-speed stored program digital computer capable of being programmed to various levels of fidelity. The purpose of this study was to discover if reduced levels of the functional fidelity in the dimension of flight airframe coefficients would be effective in training less-experienced pilots than had previously undergone training and testing on the device. Previous experimentation had been done with experienced jet pilots; the subjects in this experiment were instrument rated reciprocating engine pilots who had never flown a jet. These subjects resembled military student pilots although they did have instrument ratings which most students do not.

The variable of interest in this experiment was the flight envelope airframe coefficient, specific to any aircraft, which under real conditions changes with both speed and altitude (expressed in the simulator as the "flexible" condition). Two reduced fidelity experimental conditions were effected: (1) "Rigid airframe", where the coefficient changed with speed and not with altitude, but the configuration of change closely paralleled the changes which occur in the "flexible" condition; (2) "least squares approximation", where the coefficient changed with speed and not with altitude, but was a straight line of constant slope not paralleling the flexible coefficient configuration.

The third, "flexible" condition was the control condition and also the transfer test and retention test condition for all groups (executed in the simulator).

Three groups separately, of approximately six pilots each, were trained on the three conditions, on one maneuver: a 360 degree standard rate turn with a 2,000 fpm climb in the first half and constant altitude during the second half of the turn. All subjects and controls were then tested for transfer in the "flexible", high fidelity condition. A week to a month later, all were again tested for retention.

data, both pilot inputs (manipulations of controls) and system outputs (flight path)

(a) average absolute deviations from programmed path

(b) average algebraic deviations

(c) mean and variance of airleron and elevator surface motions, fore/aft stick, elevator trim, lateral stick, and aileron trim

(2) Questionnaire evaluations of device training by subjects and controls

f. Experimental Setting/Training Context: Laboratory, hands-on

g. Statistical Methods: non-parametric Ratio Tests; non- parametric Sign Tests

h. Variables being manipulated:

(1) Training Device: Universal Digital Operational Flight Trainer Tool, a high-speed stored-program digital computer with two simulator cockpits and an instructor station

(a) Rigid airframe coefficient data program

(b) Least-squares airframe coefficient data program

(c) Flexible airframe coefficient data (control condition and all transfer and retention test condition)

(2) Fidelity Levels:

	Rigid	Least Sqs.	Flexible
Physical	High	High	High
Functional	High	Med-high	Very High

(3) Type of Task/Skill required: operations, cognitive, psychomotor, perceptual, part-task

(4) Task Difficulty: Medium-high

i. Stage of Training: familiarization, skill, transition

j. Trainee Sophistication: intermediate to near-expert (general flying experience was moderately high)

k. Incorporation of device into P.O.I.: not applicable

l. User Acceptance of Attitude:

(1) Instructors: not discussed (experimenters ran the device)

(2) Students: not discussed, except insofar as questionnaire seemed to show they were not aware of variations in fidelity on the device

1. Authors: Ellis, N. C., Lowes, A. L., Matheny, W. G., & Norman, D. A.

2. Title: Pilot Performance, Transfer of Training, and Degree of Simulation: III. Performance of Non-Jet Experienced Pilots Versus Simulation Fidelity

3. Source: Technical Report: NAVTRADEVCEN 67-C-0034-1, August 1968

4. Topic Keywords: Flight Training ; Flight Simulation ; Flexible Coefficients ; Rigid Coefficients ; Least Square Approximation ; Transfer of Training .

5. Short Summary: Varying the functional fidelity of a simulator during flight training shows that some conditions of reduced fidelity are as effective as high fidelity in teaching certain maneuvers.

6. Device:
Universal Digital Operational Flight Trainer Tool, a high-speed stored-program digital computer with two simulator cockpits and an instructor station.

7. Institutions:

a. Sponsor: U.S. Naval Training Device Center, Orlando, FL

b. Performing Organization: Life Science, Inc. 7305 Grapevine Highway, Fort Worth, TX 76118

8. Type of Article: Experiment.

a. Number of Groups: 3

b. Description of Groups:
(1) Subjects: Approximately 6 instrument-rated pilots without jet experience, average flight time experience approximately 500 hrs.
(2) Subjects: approximately 6 same
(3) Controls: approximately 6 same

c. Tests or Trials/timing: 10 training trials; 10 transfer trials (under control condition); 10 post-training retention trials approximately 1 week to 1 month after training and transfer trials

d. Number of Different Types of Measures: 2

e. Description of Measurements and Ratings:
(1) Objective instrument-measured performance

representative of real flight requirements. Measurements of error were made in the pilots' performances and they were questioned to assess their reactions to the simulator's characteristics.

b. Results:

(1) Key Data: Correlations Between Performance Measures For Longitudinal and Lateral Parameters

Performance Parameter (Abs. Error)	Pilot	AE:p	AE:r	AE:a
Altitude	A	.15	---	-.03
	B	-.15	-.05	-.38
	C	-.56	.09	-.51
Rate of Climb	A	-.30	---	-.40
	B	-.38	.63	-.74
	C	---	---	---
Pitch Rate	A	.28	---	-.14
	B	-.58	.25	-.87
	C	-.15	.64	-.07
Elevator Deflection	A	-.17	---	-.31
	B	-.52	.31	-.68
	C	-.09	.53	-.03

(2) Verbal Description: included under CONCLUSIONS below, paragraph c.

c. Authors' Conclusions: The simulator provided a degree of simulation adequate for investigation of many pilot- vehicle variables. The initial group of maneuvers has demonstrated the feasibility of using a programmed flight path as a basis for error score computation.

g. Stat.ctical Methods: not specified

h. Variables being manipulated:
(1) Training Device: Universal Digital Operational Flight Trainer Tool, a real-time single jet aircraft simulator
(2) Fidelity Levels:
(a) Physical: unspecified
(b) Functional: unspecified. Functional fidelity was the chief variable being studied
(3) Type of task/skill required: aircraft piloting; operations; cognitive; psychomotor; perceptual
(4) Task Difficulty: high

i. Stage of Training: not applicable

j. Trainee Sophistication: expert

k. Incorporation of device into P.O.I.: not applicable

l. User Acceptance or Attitude: not specified

m. User of instructional features:
(1) Intensity: intensive
(2) Features used: not specified

9. Abstract:

a. Study Synopsis: This paper reports on a phase of a developmental study evaluating requirements for aircraft flight simulation through the use of the Universal Digital Operational Flight Trainer Tool, a real-time single engine jet aircraft flight simulator. This multiple-programmable device was capable of producing various degrees of fidelity. Topics covered in the paper were:

Previous UDOFTT Studies
Pilot Vehicle System Variables
Analysis of Piloting Tasks
Selection of Independent Variables
Variables to be Controlled
Performance Measurement
Pilot Opinion
Design of Maneuvers
Experimental Design
Preliminary Studies
Technical Requirements

In the initial pilot performance study, three highly experienced jet fighter pilots flew a series of 6 maneuvers on the device, considered to be

1. Authors: Demaree, Robert G., Norman, Don A., & Matheney, William G.

2. Title: An Experimental Program for Relating Transfer of Training to Pilot Performance and Degree of Simulation

3. Source: NAVTRADEVCEN Technical Report 1388-1, June 1965

4. Topic Keywords: Fidelity ; Flight Simulation ; Tranfer of Training .

5. Short Summary: A developmental study evaluated a number of different components of the task of flying a jet aircraft in relation to flight simulation requirements.

6. Device:
Universal Digital Operational Flight Trainer Tool, a real-time single engine jet aircraft simulator

7. Institutions:

a. Sponsor: U.S. Naval Training Device Center, Orlando, FL 32813

b. Performing Organization: Life Science, Inc. 7305 Grapevine Highway, Fort Worth, TX 76118

8. Type of Article: Experiment.

a. Number of Groups: 1

b. Description of Subjects: 3 highly experienced jet fighter pilots

c. Tests or Trials/Timing: 6 maneuvers, in-process trials

d. Number of different types of measures: 2

e. Description of measurements and ratings:
(1) Errors and deviations:
(a) Mean Squared Error
(b) Average Absolute Error
(c) Maximum deviation of a parameter from its reference value
(d) Real-time graphic recordings of deviations
(2) Subject evaluation of device

f. Experimental Setting/Training context: Laboratory, hands-on

(4) Task Difficulty: high

i. Stage of Training: skill, transition

j. Trainee Sophistication: intermediate

k. Incorporation of Device into P.O.I.: not specified, assumed lock-step

l. User Acceptance or Attitude:
(1) Instructors: moderately to highly favorable as assessed by questionnaire
(2) Students: same as instructors

m. Use of Instructional Features:
(1) Intensity: assumed intensive
(2) Features used: not specified

9. Abstract:

a. Study Synopsis: This study evaluated the effectiveness of the Carrier Air Traffic Control Center (CATCC) training device in training teams to safely and efficiently control aircraft recoveries (landings) and to effectively maintain communications necessary to implement this control function. A total of 23 CATCC personnel were observed in the trainer; subsequently, 15 of these were observed in the operational environment while performing their first scheduled Mode III aircraft recoveries. These recoveries took place two months after the final training period and were preceded by part-task OJT activities in preparation for Mode III recoveries.

Fourteen personnel from Ship One were observed in their 1st and 3rd weeks of training; 9 of these on shipboard (the transfer environment) after 1 and 3 weeks of device training and the 2-month OJT interval. Nine personnel from Ship Two were observed in their 5th week of device training, and 6 of these on shipboard after 5 weeks of device training and the 2-month OJT interval. Device effectiveness was to be assessed relative to the hypothesized superiority of Ship Two trainees due to their more lengthy practice on the simulator.

A large number of measures were taken to evaluate swiftness, accuracy, and safety of control procedures conducted by the trainees. Data were analyzed separately in respect to team performance, subteam performance, and individual performance.

b. Results:

(1) Key Data: Results are presented in a 43-page appendix which includes 19 graphs, but no overall measures which can be extracted or summarized here.

(2) Verbal Description: Team, subteam, and individual performance clearly improved as a result of device utilization. Students showed evidence of learning to contend with recovery contingencies and emergencies in the training device. The objective performance data indicate that device-trained students do perform acceptably in the operational setting after completion of training. Both students and instructors rated the trainer as moderately to highly effective. Both students and instructors rate the trainer as moderately to highly realistic in both dimensions of task environment and task performance (physical and functional).

c. Authors' Conclusions: The data indicate that each team and subteam composition tends to be a somewhat unique entity which benefits from training as an entity.

The differences in measured and observed performances between teams, subteams and individuals support the transfer of training hypothesis in that personnel with more training performed better. The evidence is not conclusive, however, because the study could not be structured so as to control or positively account for possible confounding variables.

1. Authors: Goebel, Ronald A., Baum, David R., & Hagin, William V.

2. Title: Using a Ground Trainer in a Job Sample Approach to Predicting Pilot Performance

3. Source: Technical Report: AFHRL-TR-71-50, 1971

4. Topic Keywords: Job sample ; Flight simulation ; Screening .

5. Short Summary: Evaluation of the GAT-1 light plane flight simulator as a predictor of student pilot performance in a T-41 light plane and a jet trainer increases confidence in the ability of the GAT-1 to predict flying performance via the "job sampling" method.

6. Devices:

   a. T-37 twin engine jet trainer

   b. T-41 light airplane

   c. Specially instrumented Link B-Model GAT-1 trainers, slightly modified for recording purposes

7. Institutions:

   a. Sponsor: Air Force Human Resources Laboratory , Brooks Air Force Base, TX 78235

   b. Performing Organization: Flying Training Division, AFHRL, Air Force Systems Command, Williams Air Force Base, AZ 85224

8. Type of Article: Experiment

   a. Number of Groups: 2, although there were ill-defined sub-groups

   b. Description of Groups:
      (1) Subjects: Approximately 87 undergraduate jet pilot trainees
      (2) Controls: 49 same

   c. Tests or Trials/Timing:
      (1) In-process performance evaluation (simulator)
      (2) T-41 checkride
      (3) T-37 checkrides: midphase and final

   d. Number of Different Types of Measures: 9

   e. Description of Measurements and Ratings:

(1) Subjective evaluation of simulator performance by instructors
(2) T-41 numerical score by maneuver
(3) T-41 overall nominal 4-category scale score
(4) T-41 adjusted overall grade
(5) T-37 midphase overall nominal (4-category)
(6) T-37 midphase adjusted overall nominal (4-category)
(7) T-37 final contact flight grade
(8) T-4 instrument procedures trainer (final grade)
(9) T-37 final instrument grades

f. Experimental Setting/Training Context: institutional, hands-on

g. Statistical Methods: Pearson correlations; others not specified

h. Variables Being Manipulated:
(1) Training Devices:
(a) T-37 twin engine jet trainer
(b) T-41 light airplane
(c) Specially instrumented Link B-Model GAT-1 trainer, slightly modified for recording purposes
(2) Fidelity Levels:
(a) Physical: not specified, presumably medium
(b) Functional: not specified, presumably medium
(3) Type of Task/Skill Required: aircraft piloting; operations, psychomotor, perceptual; cognitive, part-task
(4) Task Difficulty: medium and high

i. Stage of Training: introduction, transition, familiarization, skill

j. Trainee Sophistication: novice

k. Incorporation of Device into P.O.I.: not applicable (screening, not training application)

l. User Acceptance or Attitude:
(1) Instructors: favorable as judged by experimenters
(2) Students: not discussed

m. Use of Instructional Features:
(1) Intensity: not specified, presumed intensive
(2) Features used: not specified

9. Abstract:

a. Study Synopsis: Challenges to the assumption that discrete abilities measured by aptitude tests are stable and reliable predictors of the success of jet flight trainees have pointed to "job sampling" as a possible alternative method of screening candidates. In the context of this study, "job sampling" consists of "obtaining work samples during early training or simulating work situations prior to training and deriving measures of performance from either to employ as predictors of future job success." At the time of the study, the Air Force was using the T-41 light plane as a screening device for student jet pilot candidates. There was evidence that a simulator might also be used as a job sampling device.

The present experiment was designed to evaluate both the Link GAT-1 trainer and the T-41 light aircraft as predictors of student pilot performance in the T-37 twin- engine jet trainer. Prior to T-37 training, trainees in the experiment received sorties in the GAT-1 and conventional T-41 sorties on either of two schedules: (1) 6 1-hour sorties prior to T-41 phase of training; (2) 3 sorties subsequent to T-41 graduation. A control group received no GAT-1 sorties.

At the time of this report, only one predictor variable was used, a subjective evaluation of trainees by instructors based on the subjects' performance in the GAT-1 (several quantitative measures were taken but the analysis of data had not been completed at the time of the report).

Criterion variables were (1) for the T-41, numerical and overall nominal grades, and adjusted overall grade; (2) for the T-37, midphase overall nominal and adjusted overall nominal grades, and final contact grade, final procedures trainer (T-4) grade, and final instrument grade.

Correlations were made between the predictor variable and the criterion variables, from the GAT-1 to the T-41, from the T-41 to the T-37, and from the GAT-1 to the T- 37.

b. Results:

(1) Key Data: (note: numbers in parentheses are the numbers of subjects in each correlation (N)).

(a) Correclation Coefficients Between GAT-1 Instructor Evaluations and Final T-41 Adjusted Grade

Average all classes: df=104; r=+0.50, significant at .01 level

(b) Correlation Coefficients Between T-41 Adjusted Grades and T-37 Adjusted Creiteria

		T-37 Final		
Class	Midphase	Trainer	Instrument	Contact
72-04 (control)	.24 (49)	.35*(49)	.38**(49)	.29*(49)
72-05	-.09 (32)	.52**(31)	-.10 (31)	-.04 (31)
Avg (experimental class)	.12 (87df)	.38**(84df)	.16 (84df)	.19 (84df)

Note: Sample size indicated in parentheses. * Significant at .05 level. ** Significant at .01 level.

(c) Correlation Coefficients Between GAT-1 IP Grades and T-37 Adjusted Criteria

		T-37 Final		
Class	Midphase	Trainer	Instrument	Contact
72-04 (control)		-	-	-
72.05	.14 (32)	.45**(31)	.27 (31)	.31 (31)
Avg.	.23*(87df)	.29**(84df)	.16(84df)	.30**(84df)

* Significant at .05 level. ** Significant at .01 level.

(2) Verbal Description: Correlation is high between the GAT-1 instructor evaluations and final T-41 adjusted grades (table a). Results partially shown in table b have significant correlations between T-41 grade and T-37 grades in 5 out of 12 categories. Only 1 out of 12 of the correlations between the GAT-1 and the T-37 was significant. However, in comparing average correlations between tables (b) and (c), no statistically significant differences were obtained.

c. Authors' Conclusions: It is likely that measures from the light-plane ground trainer can be used to predict subsequent light aircraft performance. Also, there is often a significant relationship between light-plane flying grades and subsequent jet aircraft performance. The lack of significant differences between the average correlations of T-41-to-T-37 and GAT-1-to-T-37 suggests a tentative interpretation that a subjective measure of GAT-1 performance can potentially result in prediction equivalent to that obtainable with a like measure of light-plane performance. The present study has resulted in enough increased confidence in the ability of the GAT- 1 ground trainer to "sample the job" that research may not be addressed to the question of screening with a ground trainer in the absence of light-plane training.

1. Authors: Goett, James M., Post, Theodore J., & Miller, Gary G.

2. Title: 6883 Maintenance Training Simulator Development Utilizing Imagery Techniques.

3. Source: Air Force Human Resources Laboratory TR-80-3, May 1980.

4. Topic Keywords : Imagery ; Maintenance Training ; Simulation ; Low Fidelity ; Training Effectiveness .

5. Short Summary: This study used a low fidelity, imagery-based simulation technique in training maintenance procedures. The study produced mixed and inconclusive results, with the experimental group excelling on the most difficult task and the control group excelling on the simplest task.

6. Devices:

   a. 6883 Test Station.

   b. Low Fidelity Graphics - Line drawings with acetate overlays and marking styli for use with photographs of equipment.

7. Institutions:

   a. Sponsor: HQ Air Force Human Resources Laboratory , Brooks AFB, TX 78235

   b. Performing Organization: BioTechnology, Inc., 3027 Rosemary Lane, Falls Church, VA 22042

8. Type of Article: Experiment.

   a. Design Structure Elements:
      (1) Number of Groups: 2
      (2) Testing: Post-Tests only
      (3) Statistical Methods: ANOVA

   b. Subjects: 26 Air Force students in maintenance training

   c. Controls: 27 same

   d. Variables Being Manipulated:
      (1) Type of Training Device: Line drawings with acetate overlays and marking styli for use with photographs of equipment
      (2) Fidelity Level: Low

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(3) Type of Task: Maintenance Procedures
(4) Task Difficulty: Low
(5) Trainee Sophistication: Unspecified; presumed moderate
(6) Stage of Training: Unspecified
(7) Training Context: School
(8) User Attitude: Indifferent, as indicated by questionnaire

e. Dependent Variables (effects of manipulation)
(1) Performance Measures: Written test scored by percentage of correct steps specified in each of four tasks
(2) Supervisor Ratings: None applicable

9. Abstract:

a. This exploratory study evaluated a low fidelity, imagery-based simulation technique to determine its effectiveness in training certain avionics maintenance tasks. Subjects and controls were taught maintenance procedures for the 6883 Test Station employing (1) for experimental subjects, imagery-generating materials with a photographic mock-up of test station, (2) for controls, conventional written lists of instructions with photographic mock-up only. Testing was by written answers, referring to photographic mock-up of the 6883 station.

Four different tasks were taught; after training for each task, a test for that task was given, then the next task was taught. At the conclusion of learning and being tested on the four tasks, students took a repeated, "retention" test for Task 1 (a period of about 2 hours had elapsed since the first test for Task 1 had been given). (See Verbal Description of results).

The fact that the experimental group's performance on the "retention" test of Task 1 fell to the level of the control group's, while the control group showed no loss of learning, could be attributed to one or either of two possibilities: (1) the facilitation of the control group's learning through the training and testing on Tasks 2, 3, and 4; (2) the interference with the experimental group's learning during the same series. (See Authors' Conclusions).

b. Results:

(1) Key Data: Mean Percentage Correct for Groups on the Learning and Retention Tests of Task 1 (the most complex of the 4 tasks):

Group	Learning MEAN (Std)	Retention MEAN (Std)
Experimental (N=26)	64.8 (11.2)	51.7 (14.8)
Control (N=27)	52.6 (21.0)	51.0 (18.5)

(2) Verbal Description: On tests, groups using the imagery training materials (experimental) scored significantly better than groups using the conventional materials (control) on one out of four tasks (the most lengthy and complex); on a retention test for that same task, scores were not significantly different due to a decrement in experimental group performance. The control group significantly outscored the experimental group on one of the four tasks (the shortest and simplest).

c. Authors' Conclusions: In general, these evaluation results were mixed with respect to the effectiveness of imagery versus conventional training materials. The results suggest that the imagery training technique may be more appropriate for training more complex procedural tasks and tasks with higher spatial and psychomotor components. The unexpected success of the conventional training materials suggested the value of the equipment mock-up (photograph without other graphic aids) for procedural training.

1. Authors: Goldin, Sarah E., & Thorndyke, Perry W.

2. Title: Simulating Navigation for Spatial Knowledge Acquisition.

3. Source: Human Factors , 1982, 24(4), 457-471

4. Topic Keywords: Navigation Simulation ; Spatial Knowledge Acquisition .

5. Short Summary: This study compared different methods of information presentation in testing location knowledge acquisition. The different sources of environmental information were an actual bus tour through an unfamiliar city area, and a filmed version of the same route. The results revealed that filmed navigation can be used as an effective substitute for actual environmental experiences under some circumstances, especially for familiarization.

6. Devices:

   a. Bus tour

   b. Moving picture film

   c. Maps

7. Institutions:

   a. Sponsor: U.S. Army Research Institute , Alexandria, VA 22333.

   b. Performing Organizations: The Rand Corporation, Santa Monica, CA, and Perceptronics, Inc., Menlo Park, CA.

8. Experiment:

   a. Number of groups: 6

   b. Description of groups:
   (1)-(4) Subjects: UCLA undergraduates, randomly assigned from pool of 94 (29 males and 65 females)
   (5)-(6) Controls: Same

   c. Tests or Trials/Timing: Post-tests (battery); also aptitude tests for general ability (not measuring dependent variable)

   d. Number of different types of measures: 6

e. Description of measurements and ratings:
   (1) Descriminability in location recognition (right/wrong)
   (2) Location sequencing (right/wrong)
   (3) Estimated distances on route (continuum)
   (4) Angular error of orientation (continuum)
   (5) Angular error of landmark placement on map (continuum)
   (6) Estimated Euclidean distances on map (continuum)

f. Experimental setting/training context: Laboratory-- classroom

g. Statistical methods: ANOVA; other (if any) not specified

h. Variables being manipulated:
   (1) Training Devices
      (a) Bus Tour
         i. with map supplementation
         ii. with narrative supplementation
         iii. no supplementation (control)
      (b) Film
         i. with map supplementation
         ii. with narrative supplementation
         iii. no supplementation (control)
   (2) Fidelity Levels (of filmed simulation)
      (a) Physical: medium
      (b) Functional: none (passive learning)
   (3) Type of task/skill required: navigation; cognitive; perceptual
   (4) Task Difficulty: Medium

i. Stage of training: experimental, familiarization

j. Trainee sophistication: novice

k. Incorporation of device into P.O.I.: lock-step

l. User acceptance of attitude: not discussed

m. User of instructional features: Intensity - incomplete

9. Abstract:

a. Study Synopsis: To compare actual and simulated navigation as sources of evironmental information, an actual bus tour of an unfamiliar city environment was compared with a film of the same route shot from inside an automobile. Subjects and controls were divided into 6 groups randomly from a pool of 94 UCLA undergraduates (29 males and 65 females). Three groups of subjects rode the bus tour: of these, one group was given a supplementary map; another received an en-route narrative from an experimenter; the third, control group, received no supplementary aid. Three groups viewed the film, and received, respectively, the same supplementation.

Following the actual and filmed "tours", all groups took a battery of 6 tests designed to elicit their knowledge of landmarks, of sequence of landmarks on the route, a distance between points on route of direction of various landmarks from various positions on the route, and of configural (map) relationships between parts of the route. They were also given tests of general visual- spatial aptitude, to examine the possibilities of between-group differences in ability.

b. Results:

(1) Key Data: Summary of comparisons between Film and Tour Groups

Task Type	Result
Landmark Knowledge:	
Location recognition	Film groups more accurate than tour groups
Procedural Knowledge:	
Location sequencing	Film groups more accurate than tour groups
Route distance estimation	No difference between film _tour
Orientation judgment	Tour groups more accurate than film groups
Survey Knowledge (configural):	
Landmark placement	No difference between film and tour groups
Euclidean distance estimation	No difference between film and tour groups

(2) Verbal Description: The live tour appeared superior to the filmed tour in only one of the measured variables--"orientation judgement", which tested the ability of subjects, after envisioning themselves at various positions along the route, to indicate what direction certain landmarks lay. However, neither group performed very accurately on this task.

The influence of supplementary information on subjects' acquired knowledge was more complex than had been expected. First, only the film groups were influenced by supplementary information. Narrative supplements degraded performance when they affected it at all. Map supplements, on the other hand, sometimes enhanced performance and sometimes degraded it.

c. Authors' Conclusions: Perceptual knowledge of locations in the environment can apparently be acquired at least as well from a film as from actual navigation. Live-tour experience appears superior to simulated navigation for the acquisition of only one compenent of procedural knowledge: the angles of turns along the route. However, neither group performed very accurately on the orientation task. At least a quarter of the subjects in every group were "disoriented" according to the criterion (90 degrees off correct bearing). This low level of performance probably resulted from 3 factors: the size and complexity of the environment, the limited exposure each subject had to the environment, and the passive nature of the experience.

This study demonstrates that, under some conditions, environmental knowledge acquired through simulated navigation can be as accurate and as complete as knowledge acquired through live navigational experience. In particular, when the goal is to convey either visual detail or configural relationships, a film may provide at least as much information as a single live tour.

b. Results: Mean scores on transfer task by training group.

	Hot	Cold	Repro
Time to Train (min.)			
Mean	47.3	45.8	46.7
SD	10.6	16.7	12.2
Proficiency			
Mean	90.6	89.4	89.3
SD	1.4	1.3	1.8
Retest 1			
Mean	80.2	79.8	78.5
SD	4.2	4.0	3.0
Retest 2			
Mean	83.5	84.2	85.3
SD	2.8	3.2	5.0
Trials to Retrain			
Mean	2.3	2.3	1.8
SD	0.5	0.6	1.0
Time to Retrain (min.)			
Mean	17.3	17.0	13.4
SD	3.0	5.8	3.9

c. Author's Conclusions: The fidelity of training devices used to train men to perform procedural tasks can be very low without adverse effect on training time, level of proficiency, retention, or time to retrain. This is true whether the training is individually or group administered. Brief practice on the high fidelity device facilitates the performance of groups trained on the low fidelity panel. The low fidelity panel, in conjunction with a list of the correct actions, can be used to effectively reinstate a high level of performance after a passage of time, regardless of the panel used for original training.

A careful review of tasks to be taught should precede selection of training devices. Low fidelity devices may be used to considerable advantage both for economy in training and for effectiveness of training, remembering, and retraining.

It should be noted that the author's general conclusions are inferred from a fixed procedural task at a fairly low level of complexity (there is no branching flow in the task sequence). This is recognized by the author's statement: "the implication of this study is not that simple trainers may substitute for complex simulators, but rather that, for procedural tasks and for early stages of certain types of training, devices other than procedural trainers are uneconomical and unnecessary."

h. Variables Being Manipulated:
   (1) Training Devices:
      (a) Hot Panel (High Fidelity): physical duplicate of the tactical panel in which all lights, meters, intercom and other indicators functioned
      (b) Cold Panel (Medium Fidelity): same as above except with no electric power
      (c) Reproduced Panel (Low Fidelity): full-size artist's reproduction of Hot Panel
   (2) Fidelity Levels: High, Medium, Low
   (3) Type of Task/Skill Required: 92-step procedural task
   (4) Task Difficulty: Moderate (simple but long)

i. Stage of Training: Advanced Individual Training

j. Trainee Sophistication: Low

k. Incorporation of Device into P.O.I.: lock-step

l. User acceptance or Attitude:
   (1) Instructors: not discussed
   (2) Students: not discussed

m. Use of Instructional Features:
   (1) Intensity: not specified
   (2) Features used: not specified

9. Abstract:

a. Study Synopsis: Among 120 subjects divided into 10 groups learning 92-step procedural task on devices of differing simulator fidelity, the results showed no significant differences in training time, initial performance level, amount remembered after 4 and 6 weeks, or retraining time, between groups trained on high and those trained on low fidelity devices.

1. Author: Grimsley, Douglas L.

2. Title: Acquisition, Retention, and Retraining: Group Studies on Using Low Fidelity Training Devices

3. Source: HumRRO Technical Report 69-4, 1969

4. Topic Keywords: Procedural Task ; Fidelity ; Low Fidelity ; Retention ; Retraining ; Group Training .

5. Short Summary: Groups trained on devices of differing fidelity show no significant differences in acquisition and retention of training in procedural tasks. This data indicates that low fidelity simulators can be used for such training without adverse effects on training time, retention, or retraining time.

6. Devices: Three simulated display and control panels of differing fidelity: Hot panel (high fidelity), cold panel (medium fidelity), reproduced panel (low fidelity).

7. Institutions:

   a. Sponsor: Chief of Research and Development, Department of the Army

   b. Performing Organization:
   George Washington University Human Resources Research Office Div. 3, Presidio of Monterey, CA 93940

8. Experiment:

   a. Number of Groups: Ten Group Post Test

   b. Description of Groups:
      (1) Subjects: 120 Army trainees, excluding Mental Category IV, sex unspecified
      (2) Controls: none

   c. Tests or Trials/Timing: Post-tests over a six week period

   d. Number of different types of measures: 3

   e. Description of Measurements and Ratings:
      (1) Time to train
      (2) Proficiency scores
      (3) Time to retrain

   f. Experimental Setting/Training Context: School

   g. Statistical Methods: ANOVA

(2) Verbal Description: No measurable differences in training time to learn the procedural task, initial performance level, amount remembered after 4 and 6 weeks, or retraining time, between individuals trained on high, and those trained on lower fidelity devices.

c. Author's Conclusions: The fidelity of training devices used to train individuals on procedural tasks can be very low with no adverse effect on training time, level of proficiency, retention, or time to retrain. Training device selection should be based on a careful review of the tasks to be taught.

b. Results:

(1) Key Data: Mean scores on independent variables for experimental groups. Treatment Groups: H/H= Trained on the hot panel and tested on the hot panel; C/H= Trained on the cold panel and tested on the hot panel; C/C= Trained on the cold panel and tested on the cold panel; R/H= Trained on the repro panel and tested on the hot panel; R/R= Trained on the repro panel and tested on the repro panel.

Test	H/H	C/H	C/C	R/H	R/R
AFQT Score					
Mean	78.1	78.8	58.4	79.2	70.5
SD	22.3	20.2	20.0	10.3	23.2
GT Score					
Mean	122.0	124.0	106.0	126.0	116.0
SD	17.7	16.9	21.7	11.9	17.9
Time to Train (minutes)					
Mean	114.0	113.3	118.3	97.8	132.3
SD	21.9	30.1	30.0	30.5	37.2
Proficiency Score					
Mean	90.9	89.2	90.1	88.3	89.5
SD	1.0	3.1	1.6	3.4	3.6
Retest 1 Score					
Mean	75.7	75.0	75.4	75.1	71.7
SD	5.2	4.3	6.1	8.0	8.3
Retest 1 Score					
Mean	82.9	83.3	83.3	83.6	83.3
SD	4.6	4.8	6.5	5.0	5.5
Trials to Retrain					
Mean	2.5	2.5	2.3	2.2	2.5
SD	1.0	0.8	0.4	0.7	1.0
Time to Retrain (minutes)					
Mean	20.7	19.9	19.0	17.8	21.1
SD	10.3	6.9	4.0	8.3	10.4

Analyses of variance for these groups showed that difference were not significant.

The task to be learned required performing 92 simple procedural tasks (operation of switches, plugging in headsets, making brief verbal announcements, etc.) in proper sequence. Five groups of 12 subjects each were given training on three different devices: one group on the "Hot Panel", two groups on the "Cold Panel", and two groups on the "Repro Panel" (High, Medium, and Low Fidelity). Training was closely monitored and assisted by instructors on all panels, through unsystematic reinforcement and cueing. For events where only the powered "Hot Panel" gave automatic feedback to subject, the instructor provided verbal feedback. Subjects on "Cold" and "Repro" panels were required to speak and mime certain actions which could not be performed on their panels. Training to error-free completion of sequence required a maximum 3 hours per individual.

Immediately following training, subjects were tested and scored by alternate instructors, some on "Hot", some on "Cold", some on "Repro" panels (instructors merely counted number of correct steps completed). Then after 4 weeks, and again after additional 2 week "layoffs", subjects were retested, at this point all on the "Hot Panel"--see table below duplicated from report's "Figure 2". Following the tests they were retrained to correct errors and their retraining performance was recorded. There was no significant difference between the various trainees' performances on any tests, nor were there significant differences in their time and accuracy in relearning to correct tested errors.

All subjects retained material equally well for 6 weeks regardless of fidelity of device. Furthermore, groups remembered equally well even when they had not even seen the high fidelity device at any point in their training.

d. Number of Different Types of Measures: 1

e. Description of Measurements and Ratings:
(1) Performance Measures: Three proficiency tests over period of six weeks, scored by number of steps performed correctly, without regard to time
(2) Supervisor Ratings: none

f. Experimental Setting/Training Context: School

g. Statistical Methods: not specified

h. Variables Being Manipulated:
(1) Training Devices:
(a) High Fidelity "Hot Panel" - physical duplication of tactical panel in which lights, meters, intercom, and other indicators worked
(b) "Cold Panel" - Medium Fidelity - identical to (a) but without power
(c) "Repro Panel" - Low Fidelity - full-sized color artist's representation of (a)
(2) Fidelity Levels: High, Medium, Low
(3) Type of Task/Skill Required: 92-step procedural task, stresses learning of correct sequence and completion of all steps
(4) Task Difficulty: Low to moderate

i. Stage of Training: Advanced Individual Training

j. Trainee Sophistication: Low

k. Incorporation of Device into P.O.I.:

l. User Acceptance or Attitude: Not discussed

m. Use of Instructional Features:
(1) Intensity: Low-to-moderate
(2) Features used: not specified

9. Abstract:

a. Study Synopsis: Results of experiments studying the effect of fidelity of training devices on retention of learning were scarce and ambiguous at time of report (1969). This study (STRANGER) extends work of a previous study (RINGER) from examining acquisition only to examining retention.

1. Author: Grimsley, Douglas

2. Title: Acquisition, Retention, and Retraining: Effects of High and Low Fidelity in Training Devices

3. Source: George Washington University HumRRO Technical Report 69-1, 1969, p. 24

4. Topic Keywords: Retention ; Low Fidelity ; Fidelity ; Procedural Tasks ; Retraining ; Medium fidelity ; High fidelity .

5. Short Summary: Subjects were trained to do a procedural task on three devices of differing fidelity. No significant differences were found between subjects with regard to acquisition, retention, or retraining of ability to perform this task. The resulting implication is that procedural tasks can be trained on low fidelity simulators without adverse effects.

6. Devices: See Section 8h(1) below

a. High Fidelity "Hot Panel" - physical duplication of tactical panel in which lights, meters, intercom, and other indicators worked

b. "Cold Panel" - Medium Fidelity - identical to "a" but without power

c. "Repro Panel" - Low Fidelity - full-sized color artist's representation of "a"

7. Institutions:

a. Sponsor: Office, Chief of Research and Development, Department of the Army

b. Performing Organization: Human Resources Research Office Div. No. 3, Presidio of Monterey, CA 93940; George Washington University

8. Experiment:

a. Number of Groups: Three groups, three post-tests

b. Description of Groups:
(1) Subjects: 60 trainees in Advanced Individual Training, all with minimum score of 30 on Armed Forces Qualification Test.
(2) Controls: None (subjects all received varying degrees of simulator training)

c. Tests or Trials/Timing: post-tests

showed the simulator 1/18th as expensive as the aircraft per contact attempt.

(b) Study II: actual-aircraft checkride performance of the simulator-trained group was not significantly different from the performance of the aircraft-trained group (if anything it was slightly better). See table (b) above.

c. Author's Conclusions: The study showed that training occurs in the simulator and that it transfers very effectively to the aircraft. The cost benefits are potentially very great--estimated nearly 1 1/2 million dollars/year with present output of graduates.

The BOPTT training transfer ratio is 1:1 in the early phases of flight training but declines in the latter phases with an average of approximately 3:2 for the total flight program.

In more advanced training for instructor operators, the 100% transfer afforded by the direct substitution of the BOPTT training for aircraft training is a striking confirmation of device effectiveness.

Probably due to the extremely high proficiency of the personnel used as subjects in the skill maintenance study, the BOPTT had neither a positive nor negative effect on the maintenance of skills though refresher training, when substituted for the aircraft.

simulator exclusively; 9 controls flew an equal number of missions in the aircraft exclusively. All were then evaluated in a single real-aircraft flight mission.

In the third study, experimental subjects who were experienced operators received refresher training for skill maintenance in place of aircraft flight; the controls continued their normal flight duties without simulated training.

b. Results:

(1) Key Data:

(a) Study I: Aircraft Refueling Contact Attemps to Achieve Proficiency: All Groups

Group	N	Total Range	Total Mean
Control	16	49-126	71.06
E1	13	41-73	53.38
E2	15	41-83	53.60
E3	15	25-88	50.00

(b) Study II: Instructor Boom Operator Evaluation Check Ride Results

Group	N	Range	Mean	SD
Control	9	74.4-100	96.04	8.63
Experimental	12	88.0-100	96.37	3.98

(2) Verbal Description: No data are given from Study III because it was found that all operators in the study scored 100% regardless of group, in an initial checkride and two in-process checkrides 60 and 120 days later: no differential training effects were to be observed.

(a) Study I: as shown in table (a) above, at the 5% level of significance the experimental groups reached criterion reliabily sooner than the control group. The Boom Operator Progress Evaluation scores found the experimental groups significantly superior to the control group in the early going (before flightline training), but by the end of flightline training, there was no significant difference in performance between experimental and control groups. This rough equality was achieved by the simulator groups with 40% fewer trials in the aircraft than the controls had. Subjective interview responses from instructors agreed that the device improved the skills of students. A cost analysis was also conducted which

(2) Study II: intermediate
(3) Study III: expert

k. Incorporation of device into P.O.I.: lock-step

l. User acceptance of attitude:
(1) Instructors: very favorable as indicated by questionnaire (Study I)
(2) Students: not discussed

m. User of instructional features:
(1) Intensity: not specified, presumably intensive
(2) Features used: not specified

9. Abstract:

a. Study Synopsis: The evaluation of the Boom Operator Part Task Trainer (BOPTT), a high fidelity simulator of an aircraft refueling boom operation, was divided into three sub-studies with the following objectives:
(1) Study I: to determine the transfer of training from the BOPTT to the KC-135A aircraft for the novice boom operator student, and to evaluate the cost- effectiveness of the BOPTT in the training program;
(2) Study II: to evaluate the BOPTT effectiveness in training qualified operators to become instructors, when the BOPTT serves as the sole training device;
(3) to investigate the effectiveness of the device in maintaining skill for experienced personnel, when it is substituted for aircraft practice.

In the first study, three experimental groups of student operators unfamiliar with the task were given progressively greater amounts of simulator training prior to flightline (actual aircraft) phase of training; one of these groups was given additional simulator training during the flightline phase. The control group received no simulator training whatsoever. Numbers in each group were: experimental, 13, 15, and 13; controls, 15. Measurements were taken of number of trials to criterion, and of proficiency in the aircraft, scored by instructors and checkride observers.

In the second study, qualified boom operators were being raised to the instructor level. 12 experimental subjects were trained in the

(2) Controls: 9 same

Study III

(1) Subjects: 6 very experienced boom operators
(2) Subjects: 6 same
(3) Controls: 6 same

c. Tests or trials/timing
(1) Study I: 3 in-process trials; 1 post-test (aircraft checkride)
(2) Study II: 1 post-test (aircraft checkride)
(3) Study III: 1 in-process tests (aircraft checkrides)

d. Number of different types of measures: 2 quantitative for Study I; 1 quantitative Studies II and III; interviews with instructors, Study I

e. Description of Measurements and Ratings (quantitative)
(1) Number of trials to proficiency (Study I)
(2) "Boom Operator Progress Evaluation", instructor- scored, graded by individual skill item (all studies)

f. Experimental setting/training context: Study I, institutional, hands-on; Study II, same; Study III, field, laboratory, hands-on

g. Statistical methods: Chi-square analysis; randomized group ANOVA; Scheffe's criterion; two-way ANOVA; t-test; post hoc power analysis (Cohen, 1977)

h. Variables being manipulated:
(1) Training Devices: as above, section 6
The chief variable was the time spent on device during training. However, the results show little or no differences between the experimental groups in relation to time on device.
(2) Fidelity Levels:
(a) Physical: high
(b) Functional: high
(3) Type of Task/Skill required: boom operations; perceptual; psychomotor; procedural; part-task
(4) Task difficulty: high

i. Stage of Training:
(1) Study I: introduction, skill
(2) Study II: transition, skill
(3) Study III: expert, skill

j. Trainee sophistication
(1) Study I: novice

1. Author: Gray, Thomas H.

2. Title: Boom Operator Part-Task Trainer: Test and Evaluation of the Transfer of Training

3. Source: AFHRL-TR-79-37, October 1979

4. Topic Keywords: Cost-avoidance ; Part-task trainer ; Transfer of training ; Skill maintenance ; Simulation .

5. Short Summary: This study evaluates a high-fidelity part-task training simulator for aircraft refueling boom operation. The simulator was more effective than the real aircraft for training inexperienced students, and equally effective at training more experienced operators. Results for skill maintenance refresher training of highly experienced operators were inconclusive, although the simulator in this case did not prove inferior to the real aircraft.

6. Devices:

a. KG-135A aircraft inflight refueling boom

b. Boom Operator Part Task Trainer (BOPTT), high-fidelity ground-based simulator of flight refueling operation

7. Institutions:

a. Sponsor: HQ Air Force Human Resources Laboratory (AFSC), Brooks AFB, TX 78235

b. Performing Organization: Flying Training Division, AFHRL, Williams AFB, AZ 85224

8. Experiment (Three Sub-Studies: I, II, III)

a. Number of Groups: Study I, 4; Study II, 2; Study III, 3

b. Description of Groups:

Study I

(1) Subjects: 13 student operators, matched among groups by academic grades and initial air refueling block
(2) Subjects: 15 same
(3) Subjects: 13 same
(4) Controls: 15 same

Study II

(1) Subjects: 12 qualified boom operators training to become instructors

Several limitations of this study constrain the generality of the results. First, subjects were compared after only one simulated or live tour; repeated exposures might produce larger performance differences. Second, both tour and film groups received passive rather than active environmental experience. Third, the study examined only one simple mode of environmental simulation: a continuous film, without cuts or pans, taken from a single point of view.

1. Author: Grimsley, Douglas L.

2. Title: Acquisition, Training, and Retraining: Training Category IV Personnel With Low Fidelity Devices

3. Source: HumRRO Technical Report 69-12, 1969

4. Topic Keywords: Category IV Personnel , Low Aptitude K15;47H;15r15;H Personnel ; Procedural Tasks ; Fidelity ; Low Fidelity ; Retention ; Retraining ; Aptitude Level ; Fixed Procedure .

5. Short Summary: Low aptitude personnel trained on devices of differing fidelity show no significant difference among themselves due to fidelity in acquisition and retention of training. However, their time to learn procedural tasks is significantly greater than for higher aptitude personnel.

6. Devices: Three simulated display and control panels of differing fidelity - High, Medium, and Low

7. Institutions:

a. Sponsor: Chief of Research and Development, Department of the Army

b. Performing Organization:
George Washington University
Human Resources Research Office, Division 3, Presidio of Monterey, CA 93940

8. Type of Article: Experiment

a. Number of Groups:
(1) Two-Groups Post-Test with follow-up tests
(2) Three Sub-groups within each group

b. Description of Groups:
(1) Subjects: 72 Army trainees, sex not specified, 36 Low Aptitude (Category IV) and 36 Middle and High Aptitude
(2) Controls: None

c. Tests or Trials/Timing: Post-tests (over a period of 6 weeks)

d. Number of Different Types of Measures: 3

e. Description of Measurements and Ratings:
(1) Time to train
(2) Proficiency scores, scored by instructors, based on number of procedural tests performed

correctly, regardless of time taken
(3) Time to retrain

f. Experimental Setting/Training Context: School

g. Statistical Methods: ANOVA

h. Variables Being Manipulated:
(1) Training Devices:
(a) "Hot Panel" (High Fidelity) physical duplicate of tactical panel in which all lights, meters, intercom, and other indicators functioned
(b) "Cold Panel", identical to above except no electric power
(c) "Reproduced Panel", full-size artist's rendering of the Hot Panel.
(2) Fidelity Levels: High, Medium, Low
(3) Type of Task/Skill Required: 92-step Procedural Task
(4) Task Difficulty: Moderate (simple but long)

i. Stage of Training: Advanced Individual Training

j. Trainee Sophistication: Low

k. Incorporation of Device into P.O.I.: lock-step

l. User Acceptance or Attitude:
(1) Instructors: not discussed
(2) Students: not discussed

m. Use of Instructional Features:
(1) Intensity: not specified
(2) Features used: not specified

9. Abstract:

a. Study Synopsis: This study extends the work of HumRRO Work Unit STRANGER in examining acquisition and long- term retention of motor skills in procedural tasks, using training devices of varying degrees of simulation fidelity. The general conclusions, that low fidelity devices are quite suitable and therefore highly economical training aids for procedural tasks, are substantially the same as those arrived at in the earlier reports by Grimsley, HumRRO Technical Reports 69-1 and 69-4. The present study addresses the question of training low-aptitude personnel in a lengthy procedural task.

To compare the performances of high and low-aptitude

trainees on simulators of varying fidelity, 72 trainees were divided equally into two main groups (High Aptitude and Low Aptitude, as measured by AFQT scores with a dividing line at 30) who were to learn the 92-step procedural task. Each main group was subdivided into three sub-groups, trained respectively on High, Medium, and Low Fidelity devices--"Hot," "Cold," and "Reproduced" panels simulating a piece of Nike-Hercules control equipment.

As with earlier studies, the fidelity of the training panel had little effect on training time. Fidelity did have a slight, though for training purposes not practical, effect on initial test performances. (Reviewer's Note: The superior training effect of the High Fidelity device on the initial test scores was more pronounced among lower-aptitude subjects.)

Although large and significant differences in training and retraining time was found between High Aptitude and Low Aptitude subjects, most of the low aptitude subjects could be trained and retrained to criterion within the training time alloted under the program. In general, "the low aptitude subjects were slower to respond, required more training time to attain a specified criterion, needed more guidance and repetition of instruction, and were... more variable as a group then the middle and high aptitude subjects.' The low aptitude person can learn to perform a variety of tasks, however, if the training methods have been carefully selected and organized to facilitate his assimilation of the instruction."

b. Results:

Mean Scores (Number Correct) Transfer
By Aptitude and Training Condition

	Immediate Retention	Four-Week Retention
<u>High AFQT</u>		
Hot Panel	90.9	75.7
Cold Panel	89.2	75.0
Repro Panel	88.3	75.0
<u>Low AFQT</u>		
Hot Panel	90.5	72.4
Cold Panel	88.0	73.0
Repro Panel	86.5	72.9

On Immediate Retention test, superiority of Hot Panel-trained groups is significant ($p < .001$). Other effects not significant.

c. Authors' Conclusions: The fidelity of devices used

to train procedural tasks can be very low with no adverse effect on time to train, level of proficiency, amount remembered over time, or time to retrain. This applies to both individual and group training situations, and holds regardless of aptitude as measured by AFQT scores. Training device selection should be based on a careful review of the tasks to be taught in order to employ inexpensive (i.e., low fidelity) devices where possible.

1. Author: Grunwald, Walter

2. Title: An Investigation of the Effectiveness of Training Devices with Varying Degrees of Fidelity

3. Source: Doctoral dissertation submitted to graduate faculty, Oklahoma University at Norman, 1968; University Microfilms, Ann Arbor, MI, Order No. 68-13, 559

4. Topic Keywords: Homogeneous Grouping ; Fidelity ; Optimal Fidelity ; Low Fidelity .

5. Short Summary: Trainees who learned a procedural task on devices of five different grades of fidelity showed differences in learned proficiency apparently dependent on the involvement and effort of the learners rather than on the fidelity of the devices. Results suggested that training effectiveness may not increase, and may actually decrease, when fidelity is increased beyond an optimal level.

6. Devices:

a. Actual aircraft engineer's instrument panel, fully functional

b. Simulator with functional controls and displays

c. Mock-up with functional controls but without displays

d. Full size photograph of equipment without either functional controls or displays

e. Small illustration of equipment

7. Institutions:

a. Sponsor: Oklahoma University, Norman, OK 73069

b. Performing Organization: not applicable

8. Type of Article: Experiment

a. Number of Groups: 5

b. Description of Groups:
(1) Subjects: 25 randomly selected Air Force Flight Engineer Technicians with high technical aptitude, and with no prior experience on study equipment or similar equipment.
(2)-(5) Subjec s: 25 same

c. Tests or Trials/Timing: 3 post-test

d. Number of Different Types of Measures: 3

e. Description of Measurements and Ratings:
(1) Written multiple-choice test concerning system principles and functions
(2) Performance test, to complete procedural task under routine conditions
(3) Performance test requiring rectifying malfunctions

f. Experimental Setting/Training Context: Institutional, hands-on

g. Statistical Methods: ANOVA

h. Variables Being Manipulated:
(1) Training Devices:
(a) Actual aircraft engineer's instrument panel, fully functional
(b) Simulator with functional controls and displays
(c) Mock-up with functional controls but without displays
(d) Full size photograph of equipment without either functional controls or displays
(e) Small illustration of equipment
(2) Fidelity Levels:

Fidelity Levels:	Physical	Functional
Device a	High	High
Device b	Medium-high	High
Device c	Medium	Medium-high
Device d	Medium	Medium
Device e	Low	Medium-low

Note: These assessments of fidelity level are interpretations by the reviewer and are not fully congruent with the author's interpretation. A portion of this study is devoted in part to developing a means to describe functional fidelity.
(3) Type of Task/Skill Required: operations; cognitive; psychomotor; perceptual; procedural; part-task
(4) Task Difficulty: medium

i. Stage of Training: procedural, familiarization, skill, advanced

j. Trainee Sophistication: intermediate

k. Incorporation of Device into P.O.I.: lock-step

l. User Acceptance or Attitude: not discussed

m. Use of Instructional Features: varied; not specified

9. Abstract:

a. Study Synopsis: The purpose of this study was to evaluate the training effectiveness of five selected training devices with varying degrees of fidelity, in the learning of a specific psychomotor, procedural task--a portion of a flight engineer's preflight aircraft check. Five groups of 25 trainees each--all of whom already possessed basic ratings as Air Force Flight Engineer Technicians and who were the high aptitude--were trained on the five different devices, which ranged from actual aircraft cockpit equipment (maximum fidelity). Careful control was exercised to keep all independent variables constant, aside from the devices themselves; a preliminary study using 32 students had been performend to validate the control over the other components of the Program of Instruction.

b. Results:

(1) Key Data:

Differences Between Means of Performance Test Scores

Group	Mean
I	24.56
II	24.20
III	25.64
IV	23.72
V	22.08

Table of Differences

	II	III	IV	V
I	0.36	1.08	0.84	2.48**
II		1.44*	0.48	2.12**
III			1.92**	3.56**
IV				1.64**

** Significant on the 1 per cent level, based on critical difference d = 1.85 * Significant on the 5 per cent level, based on critical difference d = 1.40

(2) Verbal Description: There was a significant difference among the five groups in their ability to perform the task under routine conditions. The performance of the group which had received training on the mock-up was best, while performance of the group which had been trained with the aid of the small illustration was worst. Performance of the groups assigned to the remaining devices was at approximately the same level with each other.

An increase in fuctional and appearance fidelity beyond a certain point was associated with lowered effectiveness; low effectiveness also was associated with reduction of fidelity to a low value.

c. Authors' Conclusions: A training device of relatively moderate fidelity was not only more effective than devices of lower fidelity, but was also superior to devices of very high fidelity, at least in the context of this study with its emphasis on a procedural task. The present study suggests that a plateau of learning as a function of simulator fidelity is reached much sooner than has been commonly assumed, and in addition, that increasing fidelity beyond a certain optimum value may lower the effectiveness of the device.

A quantitative model, showing the relationship between learner effort and device effectiveness, helps to demonstrate the hypothesis that device effectiveness depends on the ability of the device to involve the learner in the learning process, rather than on fidelity alone.

It may be possible that contradictory research findings in the area of training device fidelity are due not to faulty experimental design, but to the present inability to state some fundamental laws governing design of training devices with respect to fidelity.

1. Authors: Hagin, William V., Durall, Edwin P., & Prophet, Wallace W.

2. Title: Transfer of Training Effectiveness Evaluation: U.S. Navy Device 2B35

3. Source: Seville Technical Report TR 79-06, July 1979

4. Topic Keywords: Flight Simulation ; Transfer of Training Weapons Delivery Training ; Training Effectiveness .

5. Short Summary: A transfer of training evaluation of a high fidelity flight simulator in advanced transitional jet pilot training showed it effective in familiarization and weapons delivery training, but ineffective in night flying training, and of unproved effectiveness in the highly advanced phase of carrier qualification.

6. Devices:

a. TA-4J jet training aircraft b. 2B35 visual display system integrated with the 2F90 operational flight trainer

7. Institutions:

a. Sponsor: Chief of Naval Education & Training Code N-4, Pensacola Naval Air Station, Pensacola, FL 32508

b. Performing Organization: Seville Research Corporation, 400 Plaza Building, Pensacola, FL 32505

8. Type of Article: Experiment

a. Number of Groups: 8 total combined in 3 separate studies
(1) Study 1: Familiarization, 3 groups
(2) Study 2: Weapons, 2 groups (6 subgroups)
(3) Study 3: Carrier Qualification, 3 groups (6 subgroups)

b. Description of Groups:
(1) Subjects: Study 1
(a) 20 advanced jet carrier pilot trainees (heavy simulator training)
(b) 20 same (moderate simulator training)
(c) 20 same (no simulator training)
(2) Subjects: Study 2
(a) 30 advanced jet carrier pilot trainees (heavy training)

(b) 30 same (not simulator training)
(3) Subjects: Study 3 (Same as Study 1)

c. Tests or trials/timing: Daily in-process trials, in simulator and in aircraft

d. Number of different types of measures: 3

e. Description of measurements and ratings:
(1) "Objective Data" scores: instructor-scored deviations from prescribed maneuver parameters
(2) Practice bomb scores: circular error
(3) Landing signal officer grades (data did not yield reliable results)

f. Experimental setting/training context: institutional, hands-on

g. Statistical methods: univariate and multivariate analysis of variance, covariance, and regression; t-test

h. Variables being manipulated:
(1) Training devices: as in section 6 above
(2) Fidelity levels (of simulator):
(a) Physical - high
(b) Functional - low
(3) Type of task/skill required: operations; cognitive, psychomotor, perceptual, procedural, whole-task
(4) Task Difficulty: high

i. Stage of training: familiarization, skill, transition, advanced

j. Trainee sophistication: intermediate

k. Incorporation of device into P.O.I.: lock-step

l. User acceptance or attitude:
(1) Instructors: moderately favorable
(2) Students: not discussed

m. Use of instructional features:
(1) Intensity: intensive
(2) Features used: Freeze capability; Restart/resequence capability; Number/quality of responses; others not specified

9. Abstract:

a. Study Synopsis: This report presents results of a

transfer of training effectiveness evaluation of a visual flight simulator, Navy Device 2B35, a computer-generated imaging, wide angle visual attachment to an operational 2F90 flight trainer being used in advanced jet training. The experiment was divided into three main parts, investigating the use of the device in (1) Familiarization, and Night Familiarization; (2) Weapons; (3) Carrier Qualification. A total of 60 Advanced Jet student pilots were subjects of the study. In part 1 of the experiment, they were divided into three groups of 20, in which one group received aircraft training and no device training and the other two received no aircraft training and different amounts of device training prior to their first aircraft flight; in part 2, Weapons, the trainees were divided into 2 groups of 30 each, in which one group received no device training while the other did; part 3 was structured the same as part 1.

Objective measurements taken during trials in the simulator, and later, trials in the aircraft, were (1) deviations from prescribed maneuver parameters, and (2) circular error in practice bombing (weapons phase only). Subjective instructor grades were also given for aircraft flights.

b. Results:

(1) Key Data: Mean Percent Error By Group And Flight: WEP Delivery Pattern

Group	Flight 5	Flight 6	Flight 7
Simulator-trained	39%	30%	39%
Non-Simulator-trained	45%	38%	38%

Reviewer's Note: These figures are approximations from a graphic representation in the report.

(2) Verbal Description: No significant difference in transfer performance resulted from device training in the carrier qualification phase, although missing data make this report inconclusive. For the Night Flying Familiarization transfer task, the only significant differences which appeared indicated superiority for the group which had no device training.

Results in the weapons delivery transfer performances, and in day familiarization, however, did show simulator training equal to or even superior to, training in the aircraft. Mean percent error in flight patterns for the weapons

aircraft trials are shown in the table above. The MVF for the weapons main treatment effect was 2.63 with 10 and 47 df; $p < .02$.

In the tests of transfer performance in the familiarization phase, few significant differences appeared among many performance measures between treatment groups, indicating that device training was as effective as aircraft training.

c. Authors' Conclusions: The transfer results presented do provide support for the continued utilization of the 2B35 in Navy Advanced Jet training. However, such support requires qualification with reference to the skills and tasks to be taught. Those results support the use of the device for familizarization maneuvers, but not without some qualifications. On the other hand, the results offer no support to the use of the device for night familiarization instruction. The clearest support for 2B35 utility is in the weapons training area, but no conclusion can reasonably be drawn in favor of use of the device in the carrier qualification phase of training.

1. Author: Hagman, Joseph D.

2. Title: Effects of Training Task Repetition on Retention and Transfer of Maintenance Skill.

3. Source: U.S. Army Research Institute for the Behavioral and Social Sciences, Research Report 1271, May 1980.

4. Topic Keywords: Task Repetition ; Retention ; Training Transfer ; Maintenance Skill .

5. Short Summary: This eperiment investigated the effects of task repetitions on the performance of a simple task. The task repetition levels varied from no (0) repetitions to four (4) repetitions of the task. An apparent ceiling of three repetitions of the tasks during training was found to enhance both acquisition of skill and 2-weeks retention of skill in task performance. However, the task repetitions did not enhance transfer of skill to other, similar equipment.

6. Device: 500A Sun Test Stand (Actual Test Equipment)

7. Institutions:

   a. Sponsor: Deputy Chief of Staff for Training, Army Training and Doctrine Command, Fort Eustis, VA 23604.

   b. Performing Organization: Army Research Institute for the Behavioral and Social Sciences, Army Training and Doctrine Command, Fort Eustis, VA 23604.

8. Type of Article: Experiment.

   a. Number of Groups: 5

   b. Description of Groups: Subjects were military fuel and electrical repairmen
      (1) 15, trained by 4 task repetitions
      (2) 15, 3 task reps
      (3) 15, 2 task reps
      (4) 15, 1 task rep
      (5) Controls: 15 same, 0 task reps

   c. Tests or Trials/Timing: 3 post tests: 1 immediately for subjects only; 1 delayed for subjects only; 1 delayed transfer-to-other-equipment for subjects and controls

   d. Number of different types of measures: 2

e. Description of Measurements and Ratings:
   (1) Time to complete tasks
   (2) Number of errors in performing tasks

f. Experimental/Training Context: unspecified; apparently laboratory, hands-on

g. Statistical Methods: One way ANOVA; mixed factorial ANOVA

h. Variables being manipulated:
   (1) Training Device: 500A Sun Test Stand; however, number of task repetitions, not device, was the variable of interest
   (2) Fidelity Levels:
      (a) Physical: exact--standard equipment
      (b) Functional: same
   (3) Type of Task/Skill required: maintenance checking psychomotor; cognitive; perceptual, procedural, part-task
   (4) Task Difficulty: Medium

i. Stage of Training: procedural, familiarization

j. Trainee Sophistication: novice and intermediate (students, but amount of prior training unspecified)

k. Incorporation of device into P.O.I.: unspecified

l. User Acceptance or Attitude: not discussed

m. Use of Instructional Features: not specified

9. Abstract:

a. Study Synopsis: The general purpose of this study was to provide information concerning the effects of task repetition on the retention and transfer of AIT-acquired maintenance skill.

75 student fuel and electrical repairmen were randomly selected and divided into five groups of 15 each. One group served as a control for only the post-experiment delayed transfer test, and received only familiarization but no training on the device (a 500A Sun Test Stand, actual maintenance testing equipment). The other four groups received, respectively, 1, 2, 3, and 4 training trials for 5 maintenance tasks, testing a 100-amp alternator with the device. The 4 experimental groups were subsequently tested for speed and accuracy of performance of the 5 maintenance-checking tasks, immediately after training,

f. Experimental setting/training context: Laboratory, hands-on

g. Statistical methods: Multivariate analysis of variance

h. Variables being manipulated:
   (1) Training Devices: as above. Four simulated variables were manipulated:
      (a) Motion: none, 3 DOF, 6 DOF
      (b) G-seat: nonoperational; intermediate; fully operational
      (c) Field of view: Full capability, intermediate capability, narrow view
      (d) Ceiling/visibility: clear and unlimited; minimum and limited ceiling
   (2) Fidelity levels:
      (a) Physical: High, with variability, in that field-of-view and ceiling/visibility were being manipulated
      (b) Functional: High, with variability, in that G- seat and platform motion were being manipulated
   (3) Type of task/skill required: operations, cognitive, psychomotor, perceptual, procedural, part-task
   (4) Task difficulty: medium-high to high

i. Stage of training: skill (not actually a training exercise)

j. Trainee sophistication: expert

k. Incorporation of device into P.O.I.: not applicable

l. User acceptance or attitude: not discussed

m. Use of instructional features:
   (1) Intensity: intensive
   (2) Features used: Cue enhancement features; Number/quality of responses; plus others not specified

9. Abstract:

a. Study Synopsis: This study constituted a follow-up investigation of the effect on experienced pilot performance of manipulating system variables within the Advanced Simulator for Pilot Training. The larger purpose of this pair of studies was to determine the relative training benefits of different variables. It

1. Authors: Irish, Philip A., & Buckland, George H.

2. Title: Effects of Platform Motion, Visual and G-seat Factors upon Experienced Pilot Performance in the Flight Simulator

3. Source: AFHRL-TR-78-9, June 1978

4. Topic Keywords: Flight Simulation ; Platform Motion ; Field-of-View ; G-seat factors ; Pilot Performance .

5. Short Summary: An investigation of the effects of four simulated variables on experienced pilot performance in the Advanced Simulator for Pilot Training finds varying degrees of influence on performance, but all system effects were overshadowed by the differences between subjects.

6. Devices: Advanced Simulator for Pilot Training

7. Institutions:

a. Sponsor: HQ Air Force Human Resources Laboratory (AFSC), Brooks AFB, TX 78235

b. Performing Organization: Flying Training Division, AFHRL, Williams AFB, AZ 85224

8. Type of Article: Experiment

a. Number of groups: 1

b. Description of groups: Subjects were 5 T-37 Instructor Pilots with 300-2,000 total flying hours (minimum of 160 in simulated aircraft)

c. Tests or trials/timing: in-process trials

d. Number of different types of measures: 3

e. Description of measurements and ratings:
(1) System output measures: deviations using the root mean square technique from specified criteria within segments of a maneuver
(2) Pilot input measures - in the form of elevator, aileron and rudder power for maneuver segments, an attempt to measure analogs of pilot workload
(3) Derived scores: composite scores for a segment or combination of segments within a maneuver, indicating how well pilot remained within tolerance limits of several criteria simultaneously

familiarity was also significant, with the most improvement due to aided training occurring for the unfamiliar powerplants.

c. Authors' Conclusions: There are three particularly important results to be noticed. (1) All groups of trainees were suboptimal in that they used operations that provided low information gain at high cost. (2) Fourth-semester trainees had a significant positive transfer of aided context-free training to context-specific tasks. (3) Aided training is of most use for transferring to unfamiliar problems.

A consistent interpretation of these and previous studies leads one to conclude that context-free training may be more consistently valuable for trainees who are farther along in their training program.

The use of context-free simulations appears quite promising.

9. Abstract:

a. Study Synopsis: Although logical fidelity is presumed to be the most important factor in simulator design-- particularly in the area of troubleshooting maintenance-- simulators are often designed with more emphasis on imitating specific real-world appearances than in developing general problem-solving skills. This study attempted to evaluate the training effectiveness of FAULT, an interactive computerized maintenance troubleshooting simulator, in teaching, via context-free tasks, general problem-solving skills which could then be applied to real-world context specific troubleshooting tasks.

Two experiments were conducted with trainees in a 2-year FAA certificate program in aircraft powerplant maintenance. Procedures and testing were the same in both experiments; however, the subjects and controls in one were 26 trainees in the 4th and final semester, in the other were 60 trainees in their 1st semester. All subjects were volunteers. Their simulator training consisted of three sessions of context-free problem-solving, wherein half of each group received interactive aid from the computer and the other half was unaided. Testing consisted of solving context specific problems in-process (after the 2nd and 3rd training sessions) and in a final post-test. The criterion in all tasks was to minimize the overall costs of solutions. Measures extracted from the data included not only overall costs but also "fine-grained" criteria quantifying the quality of the diagnostic strategy.

b. Results:

(1) Key Data: There was a significant difference between the average cost for familiar CAR problems ($49) and unfamiliar ($2271) TPE and JT12 problems-- $F(1,164)=41.28$, $p<0.01$.

(2) Verbal Description: There appears to be a negative transfer of aided training for first-semester trainees and a positive transfer of aided training for fourth-semester trainees.

For suboptimality costs it was found that the group trained with aid significantly outperformed the unaided group. The improvement was greater for first-semester trainees than for fourth-semester trainees but both were significant. The interaction of aiding and

post-test

d. Number of Different Types of Measures: 2

e. Description of Measurements and Ratings:
   (1) Overall "product" measures, e.g. cost and time-to- solution
   (2) Fine-grained "process" measures, e.g., "expected information gain per action, suboptimality (with respect to a minimal cost per bit solution) due to errors and inefficiency, and the allocation of expenditures among observations, bench tests, and unnecessary replacements."

f. Experimental Setting/Training Context: Institutional laboratory, hands-on

g. Statistical Methods: Three-factor ANOVA

h. Variables Being Manipulated:
   (1) Training Devices: FAULT interactive computerized troubleshooting simulator.
      (a) Aiding Mode
      (b) Unaiding Mode
   (2) Fidelity Levels:
      (a) Physical: low (abstract context-free)
      (b) Functional: unknown; hypothesized psychological fidelity very high (experimental)
   (3) Type of Task/Skill Required: Maintenance troubleshooting; cognitive
   (4) Task Difficulty: High

i. Stage of Training: skill

j. Trainee Sophistication: intermediate for First Experiment; novice for Second Experiment

k. Incorporation of Device into P.O.I.: Experimental self- paced

l. User Acceptance or Attitude: not discussed

m. Use of Instructional Features:
   (1) Intensity: intensive
   (2) Features used: Restart/Resequence Capability; Sign- in Capability; Number/Quality of Responses; Record/Playback (a summary of events rather than a playback); perhaps Internal Monitoring of Instructional Features; perhaps Next Activity Features

1. Authors: Hunt, Ruston M., & Rouse, William B.

2. Title: Problem-Solving Skills of Maintenance Trainees in Diagnosing Faults in Simulated Powerplants

3. Source: Human Factors , 1981, 23(3), 317-328

4. Topic Keywords: Maintenance Training ; Context-free ; Context-specific ; Fault Diagnosis Tasks ; Interactive Computer Aiding .

5. Short Summary: The real-world value of context- free training was evaluated by the testing of context- specific troubleshooting ability in subjects previously trained by context-free methods, with mixed practical, but promising theoretical results. These results suggest that context-free training would be more valuable to students further along in their training programs.

6. Devices: FAULT interactive computerized maintenance troubleshooting simulator.

7. Institutions:

a. Sponsor: U.S. Army Research Institute for the Behavioral and Social Sciences, 5001 Eisenhower Avenue, Alexandria, VA 22333

b. Performing Organization:
University of Illinois, Urbana, Illinois 61801

8. Type of Article: Experiment

a. Number of Groups: 4

b. Description of Groups: FIRST EXPERIMENT
(1) Subjects: 13 volunteer powerplant maintenance trainees in 4th and final semester of 2-year FAA certificate program in aircraft powerplant maintenance
(2) Controls: 13 same
Note: numbers 13 are assumed by equal division of pool of 26. Authors did not state how the 26 were divided.

Description of Groups: SECOND EXPERIMENT
(1) Subjects: 30 same as above but in 1st semester of course
(2) 30 same as subjects, 2nd experiment
Note: same as for 1st experiment

c. Tests or Trials/Timing: 2 in-process trials; 1

simulation (not instructional) features of the training device.)

to overtraining. This comparison points out the desirability of training to a specific performance criterion rather than to a time schedule.

(In addition, TERs and learning curves for both groups were broken out for each of the 24 maneuvers under study. The differences in effectiveness among various maneuvers were attributed to specific shortcomings of the device, particularly in visual ground reference at very low altitudes (hovering flight).

(b) Experiment 2: As shown in the above table, the simulator trained group improved its performance significantly during the training period while the untrained group did not. Furthermore, the insignificant correlation between CH-47 flight time during the evaluation period and the posttest checkrides scores means that the improvement in performance of the simulator-trained aviators was due to their training and not to experience in the aircraft.

c. Author's Conclusions: Part I on transition training and Part II on combat readiness flying both show that the CH47FS is an effective training device.... A small group of maneuvers had CTERs below 0.7. However, CTERs in the range of 0.5 to 0.7 do not indicate that this training device is ineffective. Rather, they indicate that the training device is not as efficient in terms of the number of trials required to learn a particular maneuver as is the actual aircraft.

The maneuvers that produced the lower CTERs were all maneuvers in which a substantial part of the maneuver was spent close to the ground. It is believed that these difficulties... are due primarily to limitations in the visual system. Another source of difficulty in performing and training hovering maneuvers could be the aerodynamic simulation of hovering.

To obtain the maximum benefit from the simulator, it is recommended that a minimum of time be spent training the...maneuvers with the low CTERs. The limited simulator time should be spent training those maneuvers with the highest transfer to the aircraft.

(Further recommendations were made to improve certain

b. Results:

(1) Key Data:

Experiment 1:

Cumulative Transfer Effectiveness Ratio (CTER) from Simulator to Aircraft

	CTER Trials to Criterion		CTER Time	
	Crit.6	Crit.8	Crit.8	Total
Overall (24 maneuvers)	.69	.82	.95	.70

Experiment 2:

Means and t-Tests of Pretest and Posttest Checkrides Scores for Experiment and Control Group

Group	Pretest	Posttest	t	df	p
Experimental	47.5	56.7	6.8	14	<.002
Control	52.5	53.7	.98	12	
t	2.3	1.0			
df	26.0	26.0			
p	<.05	<.4			

(2) Verbal Description:

(a) Experiment 1: In reference to the Transfer of Effectiveness Ratios shown above, the formula was:

CTER = (control group aircraft trials or time - experimental group aircraft trials or time)/experimental group simulator trials or time

These CTERs express the training effectivenss of the CF47FS if used in a training program, including all of the 24 tested maneuvers. All of the overall CTERs are conservative because of overtraining. The trials-to-criterion 8 CTER is higher than the trials-to-criterion 6 CTER due to the effect of overtraining on the trials- to-criterion 6 CTER. The time-to-criterion 8 CTER is higher than the trials-to-criterion 8 CTER because of the general time advantage of the simulator over the aircraft. The total time CTER is lower than the time-to-criterion due

m. User of instructional features:
   (1) Intensity: presumably intensive
   (2) Features used: instructional features not specified

9. Abstract:

a. Study Synopsis: This paper reports on two experiments undertaken to assess the training effectiveness of the CH47FS, a prototype high-fidelity visual helicopter flight simulator designed as a training device for the Chinook CH-47 helicopter.

The first experiment studied the transfer-of-training for 16 student pilots who received most of their transition training to the Chinook CH-47 on the simulator, and some in the aircraft (the latter chiefly in the form of checkflights). The controls were 35 students, matched for aptitude with the subjects, who received all of their training in the aircraft, in accordance with the standard course of instruction. All students were subsequently given checkrides and trained to qualification criterion--if further training was needed--in the aircraft. Dependent variables were: time to criterion; trials to criterion; and checkride grades. Results were evaluated by means of the Transfer Effectiveness Ratio developed by Roscoe (1971, 1972).

The second experiment investigated the capability of training in the simulator to keep experienced, working pilots prepared for combat. 16 subjects and 16 controls, FORSCOM aviators currently flying the CH-47, were selected for the study by company commanders according to criteria unknown to the experimenters. Subjects and controls were given pretraining and post-training checkrides and rated per maneuver. During the 6-month training period, all subjects and controls flew only mission-essential flying in the aircraft (differences between the mission flying times for the two groups during the period were found nonsignificant by t-test; outside the aircraft, the subjects received a mean 29.7 hours training on the simulator, while the controls received no training.

c. Tests or Trials/Timing:
Experiment 1: In-process trials; 1 post-test (aircraft checkride)
Experiment 2: 1 pre-test; 1 post-test (aircraft checkrides)

d. Number of different types of measures: 4

e. Description of measurements and ratings:
(1) Experiments 1 and 2: 12-point scale performance rating by maneuver (Instructor Pilot rated)
(2) Experiment 1 only: 3-point ratings of subtasks (by Instructor Pilot)
(3) Experiment 1 only: *Number of trials to criterion
(4) Experiment 1 only: *Time to criterion (flight time in simulator and in aircraft)

*(3) and (4) were the dependent variables analyzed in Experiment 1

f. Experimental Setting/Training Context:
Experiment 1: Institutional, hands-on
Experiment 2: Laboratory, hands-on

g. Statistical Methods: t-test; others (if any) not specified

h. Variables being manipulated:
(1) Training Devices: as above, section 6 Note: both simulator and aircraft were Training Devices for experimental subjects
(2) Fidelity Levels: (Simulator)
(a) Physical: Medium-high to high
(b) Functional: High
(3) Type of Task/Skill required: operations, cognitive, psychomotor, perceptual, whole-task
(4) Task Difficulty: High

i. Stage of training:
Experiment 1: introduction, familiarization, skill, transition
Experiment 2: refresher, skill, advanced

j. Trainee sophistication:
Experiment 1: not specified
Experiment 2: expert

k. Incorporation of Device into P.O.I.: lock-step

l. User Acceptance or Attitude: not discussed

1. Author: Holman, Garvin L.

2. Title: Training Effectiveness of the CH-47 Flight Simulator

3. Source: U.S. Army Research Institute for the Behavioral and Social Sciences Research Report 1209, May 1979

4. Topic Keywords: Simulation Fidelity ; Visual Flight Simulation ; Transfer of Training .

5. Short Summary: A transfer of training experiment using inexperienced student pilots, and a combat readiness training experiment using experienced pilots, showed a helicopter flight simulator effective in training for all flight maneuvers except those requiring a high degree of visual ground referencing.

6. Devices:

a. Chinook CH-47 helicopter

b. CH47FS High Fidelity Visual Flight Simulator

7. Institutions:

a. Sponsor: U.S. Army Aviation Center, Directorate of Training Developments, Fort Rucker, AL 36362

b. Performing Organization: U.S. Army Research Institute for the Behavioral and Social Sciences, 5001 Eisenhower Avenue, Alexandria, VA 22333

8. Experiment:

a. Number of Groups: Experiment 1: 2
Experiment 2: 2

b. Description of Groups:

Experiment 1:
(1) Subjects: 24 student aviators, matched with controls by Flight Aptitude Selection Test and Bennet Mechanical Comprehension Test
(2) Controls: 35 same

Experiment 2:
(1) Subjects: 16 experienced FORSCOM aviators; unmatched--selection criteria unknown to experimenters
(2) Controls: 16 same

increased transfer with increased training repetition may have been due to the lack of task variety experienced during training. It is possible that in the present experiment, added training task variety was necessary for the benefits of task repetition to be observed.

In contrast to retention, transfer performance was not a function of prior training task repetitions. The lack of a repetition effect was suggested to be a function of "floor effects" adversely operating on the transfer data or to the need for introduction of added task variety during training repetitions.

and again 14 days later without training on the device in the interval. In addition, immediately after the 14-day retention test, they were tested for performance of the 5 tasks using the same test device but checking a 60-amp alternator instead of the 100-amp alternator on which they had been trained. This last test was also given to the fifth, previously- mentioned control group who had familiarization with the testing device but no trials.

b. Results:

(1) Key Data:

Time to Complete Retentions Tests (in appx. minutes)

	Immediate	Delayed (Retention)
1-rep group	19	27
2-rep group	17	25
3-rep group	15	21
4-rep group	16	16.5

(The apparent difference in retention loss rate over time for the 4-rep group was not reliable as indicated by the nonsignificant interaction. It could have occurred by chance.)

Time To Complete Transfer Test (in approximate minutes)

0-rep Controls	43.5
1-rep group	11
2-rep group	15.5
3-rep group	14.5
4-rep group	14.25

(2) Verbal Description: Very similar results to the time measures shown above were obtained among the accuracy measures.

Only minimal hands-on training experience plus familiarization information were necessary to produce effective transfer performance.

In both retention and transfer experiments, the most errors were found in the task segment which placed the greatest emphasis on rote memorization.

c. Author's Conclusions: Maintenance task retention improved in terms of both speed and accuracy as the number of task repetitions performed during training increased. Delayed test performance was a direct function of the level of original learning attained during training. Reliable retention improvements occurred at the third training repetition with no added benefit resulting from a fourth repetition. Besides possible "floor effects" in the data, the lack of

is assumed that the responses of expert pilots to system variables can guide researchers in designing experiments with less experienced pilots in training.

The immediate objective of this particular experiment was to assess empirically the performance of experienced T-37 pilots in the simulator under varying platform motion, G-seat, field-of-view, and ceiling/visibility configurations.

Five experienced pilots, fully qualified and current in the aircraft being simulated, performed contact and instrument maneuvers (aileron roll, barrel roll, loop, 360 degree overhead pattern, GCA maneuver) in random order in the simulator under a broad range of randomly selected variable conditions, each pilot performing a total of between 14 to 21 maneuvers in the session. There were a total of 54 treatment combinations, a product of (a) three levels of Platform Motion (b) three levels of G-seat operationability, (c) three levels of Field of View, and (d) two levels of Ceiling/Visibility.

A large number of measurements were taken by way of the device's Automated Performance Measure System, which fell into three basic categories: (a) system output measures; (b) pilot input measures; (c) derived scores, the latter being composite scores which indicated how well the pilot remained within tolerance limits of several criteria simultaneously.

Data were subjected to multiple analysis of variance to account for all measured dependent variables, and to detect interactions between the various treatment conditions.

b. Results:

(1) Key Data: no tabular data were given for the subject effect, which was the most important effect found in the study, according to the authors.

(2) Verbal description; per device treatment

(a) Field-of-View: produced significant multivariate effects in four of the five maneuvers.

(b) Motion: significant multivariate motion effects were demonstrated in three of the five maneuvers: loop, overhead pattern, and GCA.

(c) G-Seat: was conspicuous by the complete absence of significant multivariate effects in any of the maneuvers.

(d) Ceiling/visibility produced multivariate and univariate significance in the two maneuvers where it was manipulated, with best performance demonstrated under the clear condition.
(e) The only interaction achieving multivariate significance was the first order platform motion by ceiling interaction in the GCA maneuver; analysis of this interaction shows all of the five measures generally associating superior performance with the clear ceiling/visibility condition.
(f) Subject effects: Consistently, subject differences accounted for the largest portion of the performance variability on each measure. This percentage ranged from 15 to 89 percent of the total variability in the performances of these maneuvers.
(g) Comparative strengths of effects other than subject: Field-of-View and Motion factors were highly variable from measure to measure. The G- seat was considerably more consistent across dependent measures and across maneuvers.

c. Authors' Conclusions: The data indicate that in comparison to subject differences and environmental factors (including ceiling/visibility), the design variables are of lesser importance.

The fact that people are different is nothing new or surprising; however, it strongly suggests that individual pilots respond to simulator configurations differently and disconfirms the hypothesis that any simple linear model of piloting behaviors is sufficient to describe the processes involved in controlling an aircraft.

The differences caused by the motion variable were often manifested in measurements particularly sensitive to pitch control. Furthermore, in some cases, the changes were more frequently recorded within the pilot input category of the dependent measures, suggesting that this variable, while often not strong enough to alter the overall performance of the vehicle, does cause changes in the pilots' controlling strategy.

Both the motion variable and the field-of-view variable together accounted for approximately 1 to 10 percent of the performance variability. The effects of field of view were generally at least equal to the effects of motion.

The existence and the nature of the subject effects and the system configuration variable effects have demonstrated the utility and efficacy of a comprehensive performance measurement strategy which addresses not only the traditional system output measures but also includes control strategy measures in the form of pilot workloads and input smoothness. The results suggest that expert pilots adapt to varying conditions often without serious degradation in the vehicle's performance, but frequently with radical changes in control stragety and information acquisition. This and the previous study have begun to identify the manner in which these changes seem to occur.

The results of this study, as they concern only experienced pilots operating within a particular device, can be generalized only with great caution.

1. Authors: Isley, Robert N., Caro, Paul W. Jr., & Jolley, Oran B.

2. Title: Evaluation of Synthetic Instrument Flight Training in the Officer/Warrant Officer Rotary Wing Aviator Course.

3. Source: Human Resources Research Office Technical Report 68-14, November 1968

4. Topic Keywords: Instrument Flight Simulation ; Training Effectiveness ; Transfer of Training .

5. Short Summary: This study used three groups of warrant officer candidates to investigate the effect of differing amounts of training time on the altered flight training. The results demonstrated that the different amounts of training time on the 1-CA-1 rotary wing flight simulator did not significantly alter instrument flight proficiency in the aircraft. Nothing else in the training program was altered, and the fifty hours of flight time normally included may account for the lack of differences in outcome measures.

6. Device: 1-CA-1 Fixed Wing Instrument Trainer modified for rotary wing flight training

7. Institutions:

a. Sponsor: Office, Chief of Research and Development, Department of the Army, Washington, DC 20310.

b. Performing Organization:
George Washington University Human Resources Research Office, Division No. 6, Fort Rucker, AL 36362.

8. Type of Article: Experiment.

a. Number of Groups: 3

b. Description of Groups:
(1) 48 Warrent Officer Candidates with introductory helicopter flight experience
(2) 46 same
(3) Controls: 51 same

c. Tests or Trials/Timing: Post-Test (Instrument Flight Checkride)

d. Number of Different Types of Measures: 6

e. Description of Measurements and Ratings:

(1) Objectively scored photographically recorded data
(2) Checkpilot checklist
(3) Checkpilot grade for flight
(4) Attrition
(5) Time to attain checkride proficiency
(6) Daily grades during training

f. Experimental Setting/Training Context: Institutional, hands-on

g. Statistical Methods: Chi-Square; ANOVA

h. Variables Being Manipulated:
(1) Training Device: 1-CA-1 fixed wing instrument trainer modified for rotary wing flight training
(2) Fidelity Levels:
(a) Physical: unspecified; presumably medium
(b) Functional: medium-low
(3) Type of Task/Skill Required: operations; cognitive; psychomotor; motor; perceptual; procedural; whole- task (helicopter instrument flight)
(4) Task Difficulty: High

i. Stage of Training: familiarization; skill; transition (to instrument flight)

j. Trainee Sophistication: intermediate

k. Incorporation of Device into P.O.I.; unspecified, presumably lockstep

l. User Acceptance or Attitude:
(1) Instructors: not specified
(2) Students: not specified

m. Use of Instrumental Features: not discussed

9. Abstract:

a. Study Synopsis: The objective of the research was to determine the extent to which skills acquired during synthetic device training in the tactical instrument phase of the Officer/Warrant Officer Rotary Wing Aviator Course enhanced subsequent trainee performance in a simulated tactical environment. The synthetic training device being used was a fixed-wing instrument flight simulator that had been modified for rotary-wing training. This was the first study of its effectiveness in training rotary wing instrument

flight, although its effectiveness had been reported for fixed wing training.

Three groups, of 48, 46, and 51 warrant officer candidates in an intermediate phase of training (transition to instrument-only flight) were given, respectively, 1, 10, and 20 hours of simulator training during an otherwise equal and standard course of instruction. The 20-hour group was the control group in that the 20 simulator training hours were a standard part of the curriculum. All candidates in the experiment also received 50 hours of real-aircraft inflight training during this phase.

All candidates were subsequently tested in a post-experiment instrument checkflight in the aircraft, and their proficiency rated according to several measures: (1) objectively scored photographic data from the checkflight; (2) checkpilot checklist for each maneuver; (3) checkpilot subjective grade for flight; (4) attrition; (5) time to attain checkflight proficiency; (6) daily grades during training.

b. Results:

(1) Key Data: Mission error rates and checkride grades. Neither of the ANOVAs performed on these data yeilded significant F ratios.

Mean Overall Mission Error Rates

	Mean	N	SD
0-hour group	21	21	7
10-hour group	22	19	9
20-hour group	23	20	8
Total	22	60	8

Mean Checkride Grades, by Group

	Mean	N	SD
0-hour group	79.25	44	7.68
10-hour group	79.80	41	8.37
20-hour group	79.22	50	7.54

(2) Verbal Description: Out of 96 flight measurements, in control and procedural instrument tasks, statistically significant differences among the experimental and control groups occurred on only three of these measures.
On other measurements of proficiency, no significant differences were to be found among the three groups.

c. Authors' Conslusions: The only reasonable conclusion from this research was that no reliable evidence was found to support the assumption that

synthetic device training administered in the modified 1-CA-1 trainer during the curriculum improves subsequent aviator performance in a tactical instrument situation.

It should be emphasized that the research described was a determination of the transfer of training value of a synthetic training program rather than of a synthetic training device. It is possible, for example, that if the present device were used differently... some evidence of beneficial transfer might be found. Preliminary results suggest that the synthetic task, as presently structured, bears little psychological resemblance to the criterion task. The physical limitations of the device are such that little or no gain in transfer of skills to the criterion situation can be expected to result from modifications to the present synthetic training program.

1. Author: Jacobs, Robert S.

2. Title: Simulator Motion as a Factor in Flight Simulator Training Effectiveness.

3. Source: U.S. Department Health Education & Welfare Education Resources Information Center Report, August 1975

4. Topic Keywords: Flight Training Simulation ; Flight Simulation ; Transfer of Training ; Motion Cues ; CostEffectiveness .

5. Short Summary: This paper presents a review of literature on the effectiveness of motion cues in flight simulation and then presents a description of an experiment in progress that is aimed at providing more accurate knowledge.

6. Devices:

a. Piper PA28R-100 Arrow single engine light aircraft

b. Singer Link GAT-2 Training Simulator; used in 3 conditions:
(1) no motion
(2) high fidelity washout motion
(3) directionally uncorrelated random-roll washout motion

7. Institutions:

a. Sponsor: University of Illinois Aviation Research Laboratory, Urbana, IL 61801.

b. Performing Organization: same

8. Type of Article: Experiment (as described; has not been implemented at time of report).

a. Number of Groups: 4

b. Description of Groups: (1)-(3) Subjects: each group, 12 volunteer student pilots without flying experience; 1 group per simulator condition. (4) Controls: 12 same, no simulator training.

c. Tests or Trials/Timing: In-process trials--trials-to- criterion are a dependent variable; criterion proficiency will be an instructor pilot judgment.

d. Number of different types of measures: 2

e. Description of measurements and ratings:
(1) Number of trials to criterion
(2) Instructor Ratings

f. Experimental setting/training context: institutional, hands-on

g. Statistical methods: ANOVA

h. Variables being manipulated:
(1) Training Devices: as above
(2) Fidelity Levels:

	(a) Physical	(b) Functional
No motion	high	medium-high
High-fidelity washout	high	high
Random-roll washout	high	medium-high

(3) Type of task/skill required: operations, cognitive, psychomotor, perceptual, whole-task
(4) Task difficulty: Medium-high

i. Stage of Training: introduction, skill

k. Incorporation of device into P.O.I.: instructor-managed

l. User acceptance or attitude: not discussed

m. Use of instructional features:
(1) Intensity: persumably to be intensive
(2) Features used: not specified

9. Abstract:

a. Study Synopsis: This study consists of a review of literature dealing with motion cues in flight simulation, and a description of an experiment which was to be conducted at the University of Illinois in hopes of clarifying the role of motion cues in simulated flight learning.

Two principal issues are discussed: (1) whether motion cues in simulation contribute to transferable learning in a cost-effective way; (2) if motion cues are valuable, what are the kinds of cues that benefit the student in transfer to the aircraft?

In regard to the former issue, a number of transfer of training studies have failed to support the notion that motion in simulator training enhances the student's later performance in the aircraft in a cost-effective

way, at least after initial contact trials have been completed.

Evidence of students' performance in the simulators, however, gives a simulator performance advantage to students who train with motion in the practice task. In one study (Koonce 1974), the difficulty of the task for the motionless simulator group apparently served to strengthen skills required for superior aircraft performance, to the detriment of simulator performance. Therefore, good simulator practice performance as a result of motion cues may transfer negatively to the aircraft.

With respect to what motion cues, if any, might contribute to transferable learning, a distinction is made between cues whose intrinsic characteristics serve the pilot as information, and cues which serve merely an alerting function--that is, during instrument flight, they merely prompt the pilot to check the instruments from whose indications he makes his decisions. The pilot knows that motion cues in real aircraft instrument flight can be misleading.

The study planned to investigate these two issues at the University of Illinois' Aviation Research Laboratory by training four groups separately in the following conditions: (1) simulation with no motion: (2) simulation with high fidelity washout motion; (3) simulation with directionally uncorrelated random-roll washout motion (in which case motion would serve only the alerting function); (4) the control condition, real single-engine light aircraft training. Transfer would be tested by students' subsequent performance in aircraft in the next, pre-solo phase of training. In this latter phase, measurements were to be the number of trials required to reach solo flight proficiency, as judged by the instructor pilot, and the number of errors to reach that proficiency.

It was expected that, if simulated motion did contribute effectively to training, that significant differences would be found between the motion groups and the no-motion group; and that, if the real value of motion cues lay in the alerting function, that the uncorrelated random roll motion group would perform at least as well as the other.

b. Results: none at the time of this paper's composition

c. Author's Conclusions: It is anticipated that this study will reveal that the provision of high fidelity roll motion simulation may facilitate the learning of simple motor control and tracking to some extent, but if Koonce's (1974) findings are generalizable to the instrument referenced flight situation, high fidelity may hinder learning as compared with no motion or directionally random motion conditions. With respect to the development of the imaginational components of piloting skill, it is difficult to predict whether motion characteristics will have any transfer implications beyond those associated with heightened realism and possibly resultant increased motivation of the student.

1. Authors: Jacobs, Robert S., Williges, Robert C., & Roscoe, Stanley N.

2. Title: Simulator Motion as a Factor in Flight-Director Display Evalualtion.

3. Source: Human Factors , 1973, 15(6), 569-582.

4. Topic Keywords: Flight Simulation ; Visual Displays ; Motion Perception ; Fidelity ; Flight Director Displays .

5. Short Summary: This experiment conducted in a high-fidelity flight simulator capable of motion shows that motion cues in simulator learning can have an important impact on performance of experimental flight-director simulated tasks. This argues for the careful interpretation of the results of research done in ground-based simulators, considering the potential effects of differences between simulated and actual flight environments.

6. Devices: Link GAT-2, high-fidelity simulator of light twin- engine instrument flight, having flight controls, flight response dynamics, and instrument indications

7. Institutions:

a. Sponsor: Engineering Psychology Programs, Office of Naval Research , jointly with Life Sciences Program, Air Force Office of Scientific Research

b. Performing Organization: Aviation Research Laboratory of the Institute of Aviation, University of Illinois at Urbana-Champaign.

8. Type of Article: Experiment.

a. Number of Groups: 2 (when results of previous study included)

b. Description of Groups:
(1) Subjects: 8 male pilots holding private pilot certificates, college students with 40-150 hours flight experience
(2) Controls: refer to Johnson, S.L., Williges, R.C., and Roscoe, S.N. "A new approach to motion relations for flight director displays" ARL71-20/ONR-71-2 AFOSR-71-6, October 1971

c. Tests or Trials/Timing: Single Post-Test

d. Number of Different Types of Measures: 1

e. Description of Measurements and Ratings: Root-mean- square error in horizontal steering performance, in 8 3-min. trials on each of 8 different simulated flight director displays

f. Experimental Setting/Training Context: Institutional; laboratory

g. Statistical Methods: Two-way and Three-way ANOVA

h. Variables Being Manipulated:
(1) Training Devices: GAT-2 high fidelity light twin engine aircraft flight cockpit simulator
(2) Fidelity Level: High
(3) Type of Task/Skill Required: Aircraft piloting; psychomotor; perceptual, cognitive
(4) Task Difficulty: High

i. Stage of Training: Skill

j. Trainee Sophistication: Intermediate

k. Incorporation of Device into P.O.I.: Unspecified; presumable self-paced

l. User Acceptance or Attitude: Not discussed

m. Use of Instructional Features: Intensive

9. Abstract:

a. Study Synopsis: High fidelity in simulators used for research purposes may be more important than in simulators used for training purposes. Although pilots use kinesthetic senses in actual flight, the contribution of simulated motion cues to understanding, performing, and learning in-flight maneuvers has not been examined parametrically. Ground-based flight simulators are incapable of providing completely realistic motion cues; moreover, for many tasks, motion cues become noise rather than signals.

This study undertook to examine, in light of the foregoing premises, what differences in test performance on simulated flight maneuvers could be attributed to the presence or lack of motion cues during simulated flight practice. Eight experienced pilots were given two practice sessions in the high-fidelity simulator of a light twin-engine aircraft, and were thereafter tested on the same device, for eight different display configurations. The three sessions were 24 hours apart. The subjects

of this experiment practiced and were tested without motion cues. The performance was compared with the performance of another, comparable group, who had undergone practice and testing by the same method in an earlier experiment, but who had been given motion cues. The test performance of those trained and tested with motion cues, for flight-director display maneuvers, was found superior to that of those who received no motion cues. The authors conclude that "it has been demonstrated that the fidelity of the motion cue structure of flight simulators has an effect upon performance levels observed in a closed-loop, man-control-display-man system.

The application of these findings to training for, and performance in, actual flight is subject to investigation.

b. Results:

(1) Key Data: Analysis of Variance Summary of Log RMS Horizontal Tracking Error comparing attitude and command mode presentations in the presence and absence of simulator motion

	df	MS	F	
Motion	1	0.0859	7.56	($p < .05$)
Subjects	14	0.0114		

(2) Verbal Description: Pilot performance in azimuth steering on the eight displays was better with simultor motion than without. When pilots flew the pursuit command steering mode, smaller RMS errors resulted. Overall, tracking performance was superior when the motion system was on as compared to off.

c. Authors' Conclusions: It has been demonstrated that the fidelity of the motion cue structure of flight simulators has an effect upon performance levels observed in a closed-loop, man-control-display-man system.... The term "fidelity" of motion cue reproduction is to some extent misleading in that it implies variation along a single dimension. In actuality, what is involved here is a multi-dimensional variable.... The issue of whether or not results in fixed-base and moving-base simulators can be extrapolated to actual flight needs to be investigated.

1. Author: Johnson, Steven L.

2. Title: Retention and Transfer of Training on a Procedural Task; Interaction of Training Strategy and Cognitive Style

3. Source: Air Force Office of Scientific Research TR 78-1161, January 30, 1978.

4. Topic Keywords: Retention of Training ; Transfer of Training ; Cognitive Style ; Mental Imagery ; Visual Imagery ; Fidelity ; Low Fidelity .

5. Short Summary: This study of a low fidelity training media which required trainees to use mental imagery found that high fidelity is not necessary in teaching this procedural task, and that vividness of imagery interacts with training strategy.

6. Devices:

a. Actual Equipment: Conveyor Line Production Control Panel

b. 35% size Photo of Actual Equipment, and pencil

c. 35% size Photo of Actual Equipment, with non-writing stylus

7. Institutions:

a. Sponsor: Life Sciences Directorate, Air Force Office of Scientific Research.

b. Performing Organization: CALSPAN Corporation, Buffalo, NY 14221.

8. Type of Article: Experiment.

a. Number of Groups: 3

b. Description of Groups:
(1) Subjects: 20 age 16-34 paid male and female volunteers without extensive previous experience in procedural tasks--"Conventional Strategy" group
(2) 18 same - "Reproduction Strategy" group
(3) 16 same - "Blind Strategy" group

c. Tests or Trials/Timing:
(1) "Proficiency confirmation trial"
(2) Delayed retention post-test, after 70 plus or minus 10 days

(3) Transfer test following delayed retention post-test

d. Number of Different Types of Measures: 3

e. Description of Measurements and Ratings:
(1) Number of trials to criterion
(2) Number of errors
(3) Time to complete trials

f. Experimental Setting/Training Context: setting/training context: laboratory, hands-on

g. Statistical Methods: analysis of variance and covariance; regression analysis

h. Variables Being Manipulated:
(1) Training Devices: as above, section 6
(a) Actual equipment, used by "Coventional Strategy" group
(b) Photo and pencil used by "Reproduction" group
(c) Photo and nonwriting stylus, used by "Blind Strategy" group
(2) Fidelity Levels:

	Physical	Functional
Actual Equipment	High	not specified
Reproduction	Low	Low
Blind	Low	Low

(3) Type of Task/Skill Required: set-up conveyor line; operations; procedural; whole-task
(4) Task Difficulty: medium

i. Stage of Training: introduction, experimental

j. Trainee Sophistication: novice-intermediate

k. Incorporation of Device into P.O.I.: not applicable

l. User Acceptance or Attitude: not discussed

m. Use of Instructional Features:
(1) Intensity: as intensive as possible
(2) Features used: virtually no simulator feedback features

9. Abstract:

a. Study Synopsis: The purpose of this study was to investigate the effectiveness of visual imagery techniques as they pertain to initial training, retention, and transfer of training. In addition to investigating the relative merit of using visual imagery versus conventional training methods, the possibility of matching instructional strategy and the trainee's cognitive style was investigated.

The task chosen for study was the operation of a control panel to set up a conveyor line production job, which required proformance of a sequence of 87 discrete simple actions. A subsequent "transfer" task consisted of 83 sequential actions.

The three training modes were (1) operating the actual equipment; (2) writing actions on a 35% size photographic reproduction of the equipment; and (3) imagining actions on the photograph, without being able to write on it (although actions could be simulated with a nonwriting stylus). 54 paid male and female volunteers, age 16-34, without extensive prior experience in procedural tasks, were divided into 3 groups, one for each training medium. The two groups trained on the low fidelity devices were briefly familiarized with the actual equipment before training began. All subjects were given two visual imagery aptitude tests in order to assess the interaction between learning and visual imagery ability.

After completion of training to a prescribed criterion, each trainee performed a "proficiency confirmation trial" on the operational, actual equipment. After a delay of from 60 to 80 days, trainees were given two retention trials, and a relearning session to criterion. They were also given a "transfer" trial on a similar task. NOTE: this "transfer" trial differs from the usual sense of transfer in that it involved a different task on the same equipment. In fact, the simulator-trained groups were given a transfer test, in the more common sense, when they operated the actual equipment in the proficiency trial.

Performance measures were: (1) number of trials to criterion; (2) number of errors in the performance of the task; and (3) time to complete trials.

b. Results:

(1) Key Data:

Measure	Conventional r	Conventional Beta	Production r	Production Beta	Blind r	Blind Beta
Initial Training						
Trials to Criterion	.38	.045**	.09	.016	.47	.103**
Total errors	.43	.802**	.25	.538	.45	1.277**
Total Training Time	.45	.861**	.22	.572	.62	2.870**
Retention Evaluation						
Total Errors	.74	.496**	.12	.040	.22	.144
Decrease in Errors	.56	.265**	.29	.083	.11	.065
Retraining						
Trials to Criterion	.48	.052**	.18	.012	.41	.035
Total Errors	.54	.424**	.22	.129	.46	.540**
Total Training Time	.51	.464**	.18	.095	.39	.393
Transfer of Training						
Trials to Criterion	.09	.009	.30	.038	.39	.076
Total Errors	.02	.017	.29	.461	.41	1.047
Total Training Time	.22	.158	.33	.443	.35	.740

** Indicates significant Beta value at $p<.05$ level.

(2) Verbal Description: The strongest effect during original training was the difference among the three groups' training times, indicated for total training time, time to perform the first trial, and time to perform the last trial. During the first trial, the conventionally trained group performed fastest, the reproduction group next fastest, the "blind" group slowest. However, only the "blind" group differed significantly in total training time and time to perform the last trial. The results of this study indicate that the total time to learn on the blind strategy is approximately 1.5 times as long as that required to learn on the conventional strategy.

There were no significant differences among the three groups in trials to criterion, or total number of errors during training, as shown in the table.

On the retention trials, the reproduction strategy was significantly superior to the conventional strategy on the basis of the total number of errors, with the blind strategy being between the other two (not significantly different from either).

Refresher training results indicated that training device fidelity does not have to be high for refresher training.

In both training and transfer portions of the experiment, no differences were significant in terms of transfer from the experimental devices to the operational equipment ($p<.25$). In the retraining portion of the study, the differences were not significant (although they were not above the .25 level).

The individual capability for vividness of imagery had a much more predominant effect within the conventional training strategy than within the other modes. Referring to the table above, 15 of the 26 relationships between imagery and the performance measures were statistically significant when using the conventional strategy. For the reproduction strategy, only one relationship was significant, while there were eight for the blind strategy. The results indicate that the conventional strategy is sufficient or possibly superior for the less vivid imager but that it handicaps the more vivid imager. Performance of low imagers was comparable to the performance of high imagers when the reproduction strategy was used.

An analysis of sex differences revealed that the females tend to be able to transfer from one task to another better than males.

c. Author's Conclusions: Vividness of imagery does interact with training strategy. Performance can be enhanced by matching the training strategy with the trainee's cognitive style.

The experimental strategies were found to have advantages for retention apparently without

accompanying problems during training. These results, along with the cost benefits of using the simpler types of devices make the use of such training methods desirable. Training devices do not need to be high fidelity for procedural tasks.

1. Author: Johnson, Steven L.

2. Title: Effect of Training Device on Retention and Transfer of a Procedural Task.

3. Source: Human Factors , 1981, 23(3), 257-272.

4. Topic Keywords: Simulation Fidelity ; Transfer of Training ; Retention of Training ; Procedural Task ; Visual Imagery .

5. Short Summary: This study compared three training devices of varying fidelity in training the same task. The conclusion was that: (1) training devices do not need to be of high fidelity to be effective in training procedural tasks, and (2) a lower-fidelity device may provide superior retention in a procedural task.

6. Devices:

   a. Actual Equipment:
   Conveyor Line Production Control Panel.

   b. 35% Photo of Actual Equipment, and pencil.

   c. 35% Photo of Actual Equipment, with non-writing stylus.

7. Institutions:

   a. Sponsor: Life Sciences Directorate,
   Air Force Office of Scientific Research.

   b. Performing Organization: CALSPAN Corporation,
   Buffalo, NY 14221.

8. Type of Article: Experiment.

   a. Number of Groups: 3

   b. Description of Groups:
   (1) "Conventional Strategy" group: 20 age 16-34 paid male and female volunteers without extensive previous experience in procedural tasks
   (2) "Reproduction Strategy" group: 18 same
   (3) "Blind Strategy" group: 16 same

   c. Tests or Trials/Timing:
   (1) "Proficiency confirmation trial"
   (2) Delayed retention post-test, after 60-80 days
   (3) Transfer test following delayed retention post-test

d. Number of Different Types of Measures: 3

e. Description of Measurements and Ratings:
   (1) Number of trials to criterion
   (2) Number of errors
   (3) Time to complete trials

f. Experimental Setting/Training Context: laboratory, hands-on

g. Statistical Methods: analysis of variance and covariance; regression analysis

h. Variables Being Manipulated:
   (1) Training Devices:
      (a) Actual equipment: conveyor line production control panel
      (b) 35% photo of acutal equipment and pencil
      (c) 35% photo of actual equipment, with non-writing stylus
   (2) Fidelity Levels:

	Physical	Functional
Actual equip.	Very High	not specified
Reproduction	Low	Low
Blind	Low	Very Low

   (3) Type of Task/Skill Required: operations; procedural; whole-task
   (4) Task Difficulty: Medium

i. Stage of Training: introduction, experimental

j. Trainee Sophistication: novice-intermediate

k. Incorporation of Device into P.O.I.: not applicable

l. User Acceptance or Attitude: not discussed

m. Use of Instructional Features:
   (1) Intensity: low
   (2) Features used: virtually no simulator feedback features

9. Abstract:

a. Study Synopsis: This study investigated three different aspects of training device effectiveness. Training device fidelity was investigated by using three different devices which required different degrees of visual imagery. The effect of training device on retention of the skill and on ability to transfer to a different procedure were also investigated.

The task chosen for study was the operation of a control panel to set up a conveyor line production job, which required performance of a sequence of 87 discrete simple actions.

The three training modes were: (1) operating the actual equipment; (2) writing actions on a 35% photographic reproduction of the equipment; (3) imagining actions on the photograph, without being able to write on it (although actions could be simulated with a non- writing stylus). These three modes were designated respectively, the "Conventional," the "Reproduction," and the "Blind."

Fifty-four paid male and female volunteers age 16- 34, without extensive prior experience in procedural tasks, were divided into three groups, one for each training condition. The two groups trained on the low fidelity devices were briefly familiarized with the actual equipment before training began. After completion of training to a prescribed criterion, each trainee performed a "proficiency confirmation trial": on the operational actual equipment. After a delay of 60-80 days, trainees were given two retention trials, and a relearning session to criterion. They were also given a "transfer" trial on a similar task.

NOTE: This "transfer" trial differs from the usual sense of transfer in that it involved a different task on the same equipment used for training the "Conventional" group. In fact, the simulator-trained groups were given a transfer test, in the more usual sense, when they operated the actual equipment in the "proficiency confirmation trial" at the conclusion of initial training.

Performance measures were: (1) number of trials to criterion; (2) number of errors in the performance of the task; (3) time to complete trials.

b. Results:

(1) Key Data:

	Strategy			Table	
	Conven.	Repro	Blind	df	F
Initial Training					
Time	71.86	84.80	106.71		
(Transformed)	8.35	9.02	10.12	2,56	4.15 $p<0.021$
Trials to					
Criterion	6.55	7.61	7.75	2,56	1.15
Total Errors	49.85	62.17	73.44	2,56	1.68
Retention					
Total Errors	42.05	37.50	39.81	2,50	3.44 $p<0.040$
Transfer Trials					
to Crit.	4.25	4.33	5.31	2,50	1.30
Total Errors	21.85	23.72	37.69		
(Transformed)	4.49	4.38	5.79	2,50	2.10

(2) Verbal Description: The strongest effect during original training was the difference among the three groups' training time. During the first trial, the conventionally trained group performed fastest, the *reproduction* group next fastest, the blind group slowest. However, only the "blind" group differed significantly in total training time and time to perform the last trial. The results of this study indicate that the total time to learn on the blind strategy is approximately 1.5 times as long as that required to learn on the conventional strategy.

There were no significant differences among the groups in trials to criterion, or total number of errors during training.

On the retention trials, the reproduction training was significantly superior to the conventional training on the basis of the total number of errors, with the "blind" training falling between the other two (not significantly different from either).

In both training and transfer portions of the experiment, no differences were significant in terms of transfer from the experimental devices to the operational equipment.

c. Author's Conclusions: A training device does not need to be of high fidelity for the training of procedure- following tasks. In fact, a low-fidelity

training condition may lead to improved retention of the initial learning.

1. Authors: Johnson, William B., & Rouse, William B.

2. Title: Training Maintenance Technicians for Troubleshooting: Two Experiments with Computer Simulations

3. Source: Human Factors , 1982, 24(3), pp. 271-276

4. Topic Keywords: Aviation Maintenance Training ; Computer Simulations ; Troubleshooting ; Context-free Training .

5. Short Summary: A comparison of computer-based simulation training with more traditional training for troubleshooting maintenance tasks finds the computer-based training competitive in transfer-of-training effectiveness, and possibly less costly.

6. Devices:

   a. Computer Simulations (experimental)

   b. Video and written materials (control)

7. Institutions:

   a. Sponsor: U.S. Army Research Institute for the Behavioral and Social Sciences

   b. Performing Organization: Aviation Research Laboratory, University of Illinois , Savoy, IL 61874

8. Experiment: (Two Experiments)

   a. Number of Groups: Experiment 1, 3; Experiment 2, 2

   b. Description of Groups:

   EXPERIMENT 1
   (1)-(2) Subjects: 12 each group, advanced aviation maintenance trainees enrolled in final course prior to FAA certification
   (3) Controls: 12 same
   EXPERIMENT 2
   (1) Subjects: 11 same as Experiment 1
   (2) Controls: 11 same as Experiment 1

   c. Tests or Trials/Timing: Post-test, both experiments

   d. Number of Different Types of Measures: 3

1. Authors: Krahenbuhl, G. S., Marett, J. R., & Reid, G. B.

2. Title: Task-specific Simulator Pretraining and In-flight Stress of Student Pilots

3. Source: Aviation, Space, and Environmental Medicine, 1978 September, 49, 1107-1110

4. Topic Keywords: Task-specific simulation ; Flight simulation .

5. Short Summary: Analysis of aircraft flight urine samples from student pilots trained with and without simulated power-on stalls and spin recoveries suggests that task-specific training in the simulator can enhance the students' emotional adaption to, and work capability on, subsequent real-aircraft flight.

6. Devices:

   a. Advanced Simulator for Undergraduate Pilot Training

   b. T-37 training jet aircraft

7. Institutions:

   a. Sponsor: United States Air Force

   b. Performing Organization: Human Performance Laboratory, Arizona State University , Tempe, AZ 85281

8. Type of Article: Experiment

   a. Number of Groups: 2

   b. Description of Groups:
      (1) Subjects: 10 USAF T-37 pilot trainee volunteers
      (2) Controls: 10 same

   c. Tests or Trials/Timing: 1 post-test (checkflight)

   d. Number of different types of measures: 2

   e. Description of Measurements and Ratings:
      (1) Urinalysis for catecholamines (preflight and postflight)
      (2) Performance Score

   f. Experimental Setting/Training Context: Institutional, hands-on

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reliable than conventional subjective ratings.

The low correlation of pilot self-evaluations with scored performance indicates low criterion-related validity.

(2) Verbal Description:

(a) Performance: only the no-motion group showed significant improvement from Day 1 to Day 2 and from Day 2 to Day 3 (simulator to aircraft). For all 3 groups, Day 3 performance in the aircraft was significantly better than Day 1 performance in the simulator. By Day 3, there were no significant differences between the three gorups for either IFR or VFR maneuvers in the aircraft.

(b) Prediction and Validation of Scoring device: the multiple correlations from Day 2 (GAT) to Day 3 (aircraft) for Groups I, II, and III, were 0.722, 0.874 ($p<0.01$), and 0.647 using the total mission scores as the criteria, and 0.763 ($p<0.05$) 0.911 ($p<0.01$), and 0.651 using the observers' overall subjective flight mission rating as the criteria. The correlations between the criteria of the total mission scores and observer overall mission ratings were 0.875, 0.852, and 0.726 for the three groups on Day 3 ($p<0.01$).

(c) Pilots' self-evaluation: the correlations between the subjects' confidence ratings and their subsequent performance of the maneuvers were not significantly greater than zero and averaged 0.262 in the simulator and 0.224 in the aircraft.

c. Author's Conclusions: The data of this study tend to support the belief that the no motion group would perform better in the aircraft on the contact maneuvers. However, they were not different from the other groups in the aircraft on the highly practiced instrument maneuvers, for the reason, apparently, that they did not develop dependence on motion cues in the simulator.

The results indicated that the sustained motion system resulted in the best prediction of aircraft flight proficiency.

The Pilot Performance Record scores' observer-to-observer correlation and its correlations with standard overall observer-rated mission scores suggest the feasibility of establishing a performance scoring device that is perhaps more quantifiable, detailed, and

their ability with their measured performance, to assess the validity of pilot's self-evaluation

90 licensed multi-engine pilots were divided into three groups matched according to experience. Each group flew two trials of ten maneuvers (5 instrument, 5 visual) on the simulator under one of three motion conditions: no-motion; sustained linear scaled-down analog motion standard on the GAT-2; and a modified "wash-out" motion that returned the simulator cab toward a near threshhold rate following the application of an acceleration. Subsequently all subjects flew the same 10 maneuvers in a Piper Aztec light twin-engine aircraft. 10 subjects from each group flew still another identical series of maneuvers in the aircraft following the first mission.

Each simulated and real mission was scored by observbers both per maneuver and per overall mission. The "Pilot Performance Record" developed by the author composed the per-maneuver rating, of which the scales were well-defined, easy to follow, descriptive of the maneuvers and behaviors being recorded, and not so demanding upon the observer as to consistute a safety hazard. The overall mission rating was a standard observer subjective rating.

Subjects also rated their confidence to perform each maneuver before their flights.

b. Results:

(1) Key Data:

Composite error scores for each group on five contact maneuvers and five instrument maneuvers (N=30/group)

Contact:	Day 1 Simulator	Day 2 Simulator	Day 3 Aircraft
No Motion Group	8.0	7.0	4.1
Sustained Motion Gp.	7.1	5.9	5.2
Washout Motion Gp.	6.2	5.5	5.3
Instrument:			
No Motion Group	5.8	4.6	3.9
Sustained Motion Gp.	5.2	4.0	4.5
Washout Motion Gp.	5.0	3.7	3.9

Reviewer's Note: The foregoing figures are my approximations for graphic representation of the data.

f. Experimental setting/training context: Laboratory, hands-on

g. Statistical methods: ANOVA; ANOVA SPF-p.q. design; Sheffle tests; Pearson product-moment correlations

h. Variables being manipulated:
  (1) Training devices: as above, section 6
    GAT-2 flight simulator, 3 conditions
    (a) No motion
    (b) Sustained linear scaled down analog motion
    (c) Washout motion
  (2) Fidelity Levels:

	Physical	Functional
No Motion	High	Medium
Sustained Motion	High	Medium-high
Washout Motion	High	Medium-high

  (3) Type of task/skill requred: operations; cognitive; psychomotor; perceptual; part-task
  (4) Task difficulty: Medium-high

i. Stage of training: familiarization, skill

j. Trainee sophistication: intermediate

k. Incorporation of device into P.O.I.: lock-step

l. User Acceptance or Attitude: not discussed

m. Use of instructional features:
  (1) Intensity: not specified; presumed intensive
  (2) Features used: not specified

9. Abstract:

a. Study Synopsis: The purpose of this study was fivefold:
  (1) to determine if flying proficiency can be predicted from performance in a ground-based simulator;
  (2) if simulators yield predictive validity, how is it influenced by simulator motion conditions;
  (3) to validate a pilot performance scoring device developed by the author;
  (4) to compare the aforementioned scoring device with traditional subjective ratings of pilot performance;
  (5) to compare pilots' level of confidence in

1. Author: Koonce, Jefferson M.

2. Title: Predictive Validity of Flight Simulators as a Function of Simulator Motion

3. Source: Human Factors , 1979, 21(2), 215-223

4. Topic Keywords: Flight simulation ; Motion cues ; Predictive validity ; Training effectiveness .

5. Short Summary: A study of the effects of levels of motion on training effectiveness and the predictive validity of flight simulators through a transfer of training design, found that simulator motion did not result in better aircraft performance, and higher predictive validity was found with very basic sustained motion.

6. Devices:

   a. Piper Aztec light twin-engine aircraft

   b. GAT-2 flight simulator

7. Institutions:

   a. Sponsor: Life Sciences Program, Air Force Office of Scientific Research

   b. Performing organization: University of Illinois at Urbana-Champaign

8. Type of Article: Experiment

   a. Number of Groups : 3

   b. Description of Groups:
   (1)-(3) Subjects: each group, approximately 30 volunteers multi-engine FAA licensed instrument-rated pilots, matched for total multi-engine flying time and amount of instrument flying time logged during past 6 months

   c. Tests or trials/timing: 1 post-test (checkflight); 2nd post test (checkflight) for 1/3 of participants

   d. Number of different types of measures: 3

   e. Description of measurements and ratings:
   (1) Observers' ratings for each maneuver (Pilot Performance Record)
   (2) Observers' overall rating for each mission
   (3) Student pilots' self-confidence ratings

context-free tasks to the equipment-specific simulations. This transfer is most pronounced when students can work on the problems in a self-paced situation using computer aiding. Results were to some extent dependent on the level of experience of the trainees; less-experienced trainees showed less transfer from computer-aided to unaided contexts.

c. Authors' Conclusions: Transfer studies need to be continued, to determine the degree of transfer from context-free tasks and equipment-specific simulations to hands-on, actual equipment troubleshooting.

RESEARCH EFFORT 3 (Adaptive Computerized Training System)

a. Study Synopsis: The Adaptive Computerized Training System employs a computer-generated model of "expert" decision-making which is compared with student decision- making during the performance of simulated troubleshooting tasks. The student receives feedback from the computer to help make his/her decisions more like an expert's. This research differs from those previously discussed in that here the context is task-specific.

b. Results: The learning algorithms in the system do learn to predict human performance. Student performance improves with practice on the system, even when no feedback based on the student model is provided. In simulation studies, similar sets of utilities produce similar troubleshooting strategies, while dissimilar sets of utilities produce dissimilar troubleshooting strategies.

c. Authors' Conclusions: Further evaluation of training and cost effectiveness of the ACTS are to be made.

logic circuit diagrams at a lower level of complexity than with the first group (Logic Game Group); (3) chance game-playing followed by reading logic circuit diagrams at the same level of complexity as the second group (Control Game Group). Groups were then tested for transfer by attempting to solve logic circuit diagrams at various levels of complexity including the highest.

b. Results: Two general trends were evident in performance in the transfer test. The Logic Control Group was superior to the Game Control Group. The Logic Game Group was in the middle, significantly worse than the Logic Control Group in terms of accuracy scores, but no performance scores; and significantly better than the Game Control Group in terms of performance scores, but not accuracy scores. The second trend is that the Logic Game Group performed more like the Game Control Group on the diagrams of intermediate complexity, and more like the Logic Control Group on diagrams of high complexity.

c. Authors' Conclusions: Under certain conditions, limited practice in reading logic circuit diagrams, when combined with playing a logic game like the one used here, is as effective as the same amount of time spent in practicing reading a more extensive set of diagrams. This is not true when the limited practice is combined with playing a game of chance, so results cannot be attributed to any general transfer effects of game playing per se. Because both game groups had the same practice set of diagrams, it also cannot be argued that limited practice was sufficient for successful performance on the transfer test.

RESEARCH EFFORT 2 (Fault Diagnosis: Context-free Trouble-shooting)

a. Study Synopsis: Research in the area of "Human Performance in Fault Diagnosis Tasks" hypothesizes skills common to all fault diagnostic tasks. Experiments in this area investigated the transfer of training from one context-free task to another, and from context-free tasks to equipment-specific tasks.

Five experiments were performed, using engineering students and aviation mechanic trainees in first and in fourth semesters.

b. Results: Some positive transfer was observed. Positive transfer did take place in some cases between the two levels of context-free tasks, and from the

e. Description of Measurements and Ratings: Cost, based on
(1) Time to complete action
(2) Cost of replacement items

f. Experimental Setting/Training Context: Laboratory, hands-on

g. Statistical Methods: not specified

h. Variables Being Manipulated:
(1) Training Devices: Computerized context-free troubleshooting simulator
(2) Fidelity Levels:
(a) Physical: Low
(b) Functional: Medium-high
(3) Type of Task/Skill Required: cognitive, psychomotor, perceptual
(4) Task Difficulty: Medium to medium-high

i. Stage of Training: experimental

j. Trainee Sophistication: novice in experiments 1 and 2; beginning in experiment 4; intermediate-advanced in experiments 3 and 5

k. Incorporation of Device into P.O.I.: lock-step

l. User Acceptance or Attitude: not discussed

m. Use of Instructional Features:
(1) Intensity: intensive
(2) Features used: not specified

9. Abstract: This preliminary report describes three research efforts in progress in the area of computer-based maintenance simulation. The advantages of computer-based simulations are in cost, versatility of simulation, range of available instructional strategies, and adaptability to individual student differences. This study is aimed at developing ways to train generalized student skills that can be applied to variety of items of equipment.

RESEARCH EFFORT 1 (Game-based Learning)

a. Study Synopsis: The first research effort, labeled "Game-based Learning," investigated the effectiveness of computer game-playing in teaching the reading of logic circuit diagrams. Three groups received training via (1) conventional instruction in logical functions and reading logic circuit diagrams (Logic Control Group); (2) logic game-playing followed by reading

(2) "Performance" (quantity of work done correctly)

f. Experimental Setting/Training Context: Laboratory, hands-on

g. Statistical Methods: not specified

h. Variables Being Manipulated:
(1) Training Devices:
(a) Computer games
(b) Computerized context-free troubleshooting simulator
(c) Adaptive Computerized Training System employing artificial intelligence
(2) Fidelity Levels:
(a) Physical: Low
(b) Functional: Low to medium-low
(3) Type of Task/Skill Required: cognitive, psychomotor
(4) Task Difficulty: medium-high

i. Stage of Training: experimental

j. Trainee Sophistication: experimental

k. Incorporation of Device into P.O.I.: not applicable

l. User Acceptance or Attitude: not discussed

m. Use of Instructional Features:
(1) Intensity: intensive
(2) Features used: not specified

RESEARCH EFFORT 2: FAULT DIAGNOSIS (CONTEXT-FREE TROUBLESHOOTING)

a. Number of Groups: 15

b. Description of Groups:
(1) Experiment One: 3 groups engineering students
(2) Experiment Two: 3 groups same
(3) Experiment Three: 3 groups Aviation mechanics trainees, 4th semester
(4) Experiment Four: 3 groups same, 1st semester
(5) Experiment Five: 3 groups same, 4th semester

c. Tests or Trials/Timing: post-tests

d. Number of Different Types of Measures: 1

1. Authors: Knerr, Bruce W., Simutis, Zita M., & Johnson, Richard M.

2. Title: Simulation Approaches to Maintenance Training

3. Source: U.S. Army Research Institute Technical Report 544, 1980

4. Topic Keywords: Transfer of Training ; Game-based Learning ; Computer-Assisted Instruction ; Maintenance Training ; Instructional Games ; Context-free Fault Diagnostic Tasks ; Artificial Intelligence .

5. Short Summary: Research efforts underway to develop ways of training generalized student maintenance skills through computer-based simulation suggest promising paths of investigation.

6. Devices:

   a. Computer games

   b. Computerized context-free troubleshooting simulator

   c. Adaptive Computerized Training System employing artificial intelligence

7. Institutions:

   a. Sponsor: U.S. Army

   b. Performing Organization: U.S. Army Research Institute for the Behavioral and Social Sciences, 5001 Eisenhower Ave., Alexandria, VA 22333

8. Type of Article: Experiment (two sets of experiments)

   RESEARCH EFFORT 1

   a. Number of Groups: 3

   b. Description of Groups:
      (1)-(2) Subjects: each 14 Army enlisted personnel
      (3) Controls: same

   c. Tests or Trials/Timing: post-test

   d. Number of Different Types of Measures: 2

   e. Description of Measurements and Ratings:
      (1) Accuracy

(2) Verbal Description:

(a) Experiment 1: "The Video trainees had significantly higher average performance index than those trained with either of the computer simulations, $F(2,33) = 6.27$, $p < 0.01$."

"The Video trainees were not significantly faster than the TASK and FAULT trainees; however, the Video trainees did have a significantly higher evaluator's rating, $F(2,33) = 4.92$, $p < 0.025$."

"Performances with the simulations were good enough to equal those with Video, as long as explicit solution sequences were not presented in Video."

(b) Experiment 2: "There were no significant differences between training methods for any of the three performance measures: average performance index, $F(1,20)=0.89$; average time, $F(1,20) = 1.31$; and average evaluator's rating, $F(1,20)=0.09$. TASK/FAULT did improve relative to Video in Experiment 2."

c. Authors' Conclusions: An appropriate combination of low and moderate fidelity computer simulations can provide sufficient problem-solving experience to be competitive with the more traditional lecture-demonstration form of instruction. The computer-based methods described herein...offer possibilities for lowering the cost of training."

maintenance troubleshooting tasks versus more traditional methods of instruction. Subjects in both experiments were advanced avionics maintenance trainees enrolled in the final course prior to FAA certification. The control training media in both experiments were videotaped programs supplemented with troubleshooting reading assignments and on-line quizzes. The video programs included highly context-specific information on the transfer tasks. There were two experimental training conditions in Experiment 1: one group, TASK, performed complex context- free problem-solving tasks, while the other, FAULT, performed a mixture of context-free tasks and tasks which provided some context-specific information. In Experiment 2, there was only one experimental group, TASK/FAULT, whose instruction hybridized the context-free TASK with the context-specific FAULT program, to emphasize the best features of each.

The transfer testing in both experiments consisted of five real troubleshooting problems on live aircraft engines. Performance was measured in terms of (1) "average performance index," an average of scores given by the evaluator to each separate trainee action on a 1-5 scale with 5 being best; (2) "adjusted time"; (3) "evaluator's rating", an overall test score assigned by the evaluator at the conclusion of each problem.

b. Results:

(1) Key Data:

EXP 1 Average Performance Index for Each Problem

Problem	TASK	FAULT	VIDEO
Spark Plug	3.62	3.93	4.29 *
Secondary Wire	3.76	3.74	4.52 *
Fuel Obstruction	4.37	4.32	4.42
Starter Lead	4.07	4.12	4.29
Oil Pressure	3.99	3.77	4.32 *

* problems explicity shown in Video program

EXP 2 Average Performance Index for Each Problem

Problem	TASK/FAULT	VIDEO
Spark Plug	4.20	4.62 *
Secondary Wire	3.82	4.26
Fuel Obstruction	4.11	4.10
Starter Lead	3.78	3.99
Oil Pressure	3.74	3.86 *

* problems explicity shown in Video program

e. Description of Measurements and Ratings:
(1) Average performance index (reflects average quality of sequence of actions taken by subject, scored on standardized observation forms)
(2) Adjusted time (real time to solution adjusted to manufacturer's labor time schedule)
(3) Evaluator's rating: overall performance score

f. Experimental Setting/Training Context: institutional, hands-on

g. Statistical Methods: not specified

h. Variables Being Manipulated:
(1) Training Devices:
EXPERIMENT 1
(a) Computer Simulation (experimental groups)
i. TASK: complex variations of context-free diagnostic tasks
ii. FAULT: context-specific simulations
(b) Videotape and written (Control group)
EXPERIMENT 2
(a) Computer simulation combining both TASK and FAULT (from Experiment 1) with modifications (Experimental group)
(b) Same as Experiment 1 (Control group)
(2) Fidelity Levels:

	Physical	Functional
TASK	Unknown	Low
FAULT	Unknown	Medium
VIDEO	Medium-low	Medium-low

(3) Type of Task/Skill Required: maintenance, cognitive, psychomotor, perceptual, procedural, part-task
(4) Task Difficulty: medium-high

i. Stage of Training: skill; transition; advanced

j. Trainee Sophistication: intermediate

k. Incorporation of Device into P.O.I.: lock-step

l. User Acceptance or Attitude: not discussed

m. Use of Instructional Features: not specified

9. Abstract:

a. Study Synopsis: Two transfer-of-training experiments were conducted to evaluate the training effectiveness of computer simulations of avoinics

g. Statistical Methods: ANOVA

h. Variables being manipulated:
   (1) Training Devices:
      (a) Advanced Simulator for Undergraduate Pilot Training
      (b) T-37 jet aircraft (test device)
   (2) Fidelity Levels:
      (a) Physical: (of simulator) high
      (b) Functional: (of simulator) high
   (3) Type of Task/Skill Required: aircraft piloting; operations; cognitive, psychomotor; perceptual; procedural; part-task
   (4) Task Difficulty: high

i. Stage of Training: familiarization; skill

j. Trainee Sophistication: novice to intermediate

k. Incorporation of device into P.O.I.; lock-step

l. User Acceptance or Attitude: not discussed

m. User of Instructional Features:
   (1) Intensity: unspecified, presumably intensive
   (2) Features used: not specified

9. Abstract:

a. Study Synopsis: The purpose of the investigation was to determine the effectiveness of ASPT spin recovery pretraining in reducing the stress experienced during the first in-flight exposure to power-on stalls and spin recoveries during T-37 pilot training.

Twenty USAF student pilots were placed into matched pairs according to simulator flying ability and the members of each pair were randomly assigned to separate groups. Th experimental group received 80 minutes of ASPT practice on power-on stalls and spin recoveries prior to the first SPIN ride in the aircraft; the control group did not recieve simulation practice on power-on stalls and spin recoveries, but both groups experienced ASPT training for take-offs, 60 degree turns, slow flight, approaches, and landings. Urine samples of the pilots were taken shortly before and after the flight and analyzed for quantities of catecholamines-- epinephrine and norepinephrine--which are indicators of emotional stress. The flight excretions were compared with the same pilots' excretions during a non-stressful period prior to the aircarft flight.

b. Results:

(1) Key Data:

Comparison of Experimental and Control Groups
Mean + S.E.M.

Condition/Variable	Experimental	Control	p=
Basal			
Epinephrine (ng/min)	4.4 + 0.7	3.8 + 0.6	0.523
Norepinephrine	37.6 + 4.5	34.8 + 3.9	0.649
Catecholamine	42.0 + 4.7	38.6 + 3.7	0.589
NE/E Ratio	10.6 + 2.2	11.9 + 2.4	0.677
Spin			
Epinephrine (ng/min)	20.1 + 3.2	38.4 + 8.0	0.047
Norepinephrine	58.7 + 6.7	43.9 + 6.2	0.120
Catecholamine	78.9 + 8.7	82.3 + 9.7	0.795
NE/E Ratio	3.4 + 0.5	1.5 + 0.3	0.004
Performance Score	29.8 + 0.9	29.4 + 1.2	0.794

(2) Verbal Description: The catecholamine excretion means for the experimental and control groups did not differ significantly. However, the difference in the ratios of norepinephrine to epinephrine was significant at the the 0.004 level of confidence.

c. Authors' Conclusions: The significant difference in the NE/E ratios for the two groups has important implications. Epinephrine excretion is sensitive to emotional arousal and has been reported to correlate with feelings of anxiety and apprehension. High levels... have been shown to accompany mental excitement, confusion, and tremor, all of which indicate lack of control and could adversely affect piloting abilities. Norepinephrine excretion, however, has been shown to rise with physical and mental stress where events are under the control of the subject.

Thus it appears that ASPT exposure and practice on power-on stalls and spin recoveries results in a stress response of a somewhat different nature wherein lower emotional arousal and perhaps a greater amount of mental work are experienced during the initial SPIN exposure in the aircraft.

1. Author: Lintern, Gavan

2. Title: Transfer of Landing Skill after Training with Supplementary Visual Cues

3. Source: Human Factors , 1980, 22(1), 81-88

4. Topic Keywords: Aircraft Flight Simulation ; Visual Cues ; Landing Training ; Transfer of Training .

5. Short Summary: A simulator-to-simulator, transfer of training experiment showed that adaptive augmented- feedback simulator training had a significantly positive effect on airplane landing performance.

6. Device: Singer-Link GAT-2 general function trainer with closed-loop visual display system (GAT/VDS)

7. Institutions:

a. Sponsor: Life Sciences Program, Air Force Office of Scientific Research

b. Performing Organization: Aviation Research Laboratory, Institute of Aviation, University of Illinois at Urbana-Champaign

8. Type of Article: Experiment

a. Number of Groups: 4

b. Description of Groups:
(1) Subjects:
(a) 12 flight-naive males 18-30 years old
(b) 12 same
(c) 12 same
(2) Controls: 12 same

c. Tests or Trials/Timing: 20 in-process criterion trials, and (for 3 subjects) post-experiment checkflight on aircraft

d. Number of Different Types of Measures: 2

e. Description of Measurements and Ratings:
(1) Unspecified method of scoring criterion trials in simulator
(2) Flight instructor ratings (aircraft flight, post- training)

f. Experimental Setting/Training Context: Laboratory, hands-on

g. Statistical methods: not specified

h. Variables being manipulated:
(1) Training Device: Singer-Link GAT-2 general function trainer with closed-loop visual display system (GAT/VDS)
(a) Constant augmentation cues
(b) Adaptive augmentation cues
(c) Flight path tracking cues
(d) Primary control (no supplementary visual cues)
(2) Fidelity Levels:
(a) Physical: unspecified, presumably medium-high
(b) Functional: medium-high to high
(3) Type of Task/Skill Required: cognitive, psychomotor, motor, perceptual, procedural, part-task
(4) Task Difficulty: Medium-high

i. Stage of Training: introduction, familiarization, skill

j. Trainee Sophistication: novice

k. Incorportion of device into P.O.I.: not specified

l. User Acceptance or Attitude: not discussed

m. Use of Instructional Features:
(1) Intensity: not specified
(2) Features used: Augmented feedback; adaptive syllabus

9. Abstract:

a. Study Synopsis: This study, using an aircraft simulator with a variety of available closed-loop, computer generated visual displays, examined adaptive training, and secondarily the applicability of an augmented feedback technique to the learning of aircraft flight tasks, specifically, the landing task.

Adaptive training was defined as "a technique in which the training scehdule is individualized by varying task difficulty in a way that is related to the student's speed of learning." The augmented feedback technique was felt to most closely represent the adaptive-training technique out of the computer-generated displays available on the device.

After initial training on the device, 4 groups of 12

flight-naive subjects each performed trial approach-and- landings on the simulator, each using one of the 4 displays available: (1) Primary Control Group, a computer-generated skeletal airport scene consisting of a horizon line and a runway outline with centerline and aiming bar; (2) Flightpath Tracking Group, a fixed cross and a moving square projected onto the screen; (3) Constant Augmented-Feedback Group, in addition to airport graphics used for the Primary Control Group, command guidance cues that showed the desired flightpath during the approach, proper height for flare, and an extended centerline; (4) Adaptive Augmented-Feedback Group, same as the latter except that the command guidance cues appeared only when the subject deviated from specified performance criteria.

Some subjects also subsequently performed real-aircraft landings and were scored by Instructor Pilots.

b. Results:

(1) Key Data

Group Statistics and Comparisons among training treatments for frequencies of criterion performances during Landing Approach Trials 21 to 36

	Primary Control (PC)	Constant Augmentation (CA)	Adaptive Augmentation (AA)	Flight path Tracking (FT)
Mean	4.58	4.75	8.33	3.58
S.D.	2.50	2.93	2.50	2.99

Comparisons

	Mean Diff.	df	t	p
CA vs PC	0.17	44	0.15	0.882
AA vs PC	3.75	44	3.35	0.002
AA vs CA	3.58	44	3.20	0.003
FT vs PC	-1.00	44	-0.89	0.376

(2) Verbal Description: During the first 20 trials, the adaptive augmented-feedback group produced the best performance, although neither of the comparisons with the constant augmented-feedback group or the primary control group were statistically reliable. During trials 21 to 36 the adaptive augmented- feedback group outperformed both the constant augmented-feedback group and the primary control group ($p<0.01$), shown above.

Unassisted landings and subjective performance ratings by qualified flight instructors showed that the students who attempted to land the airplane after their simulator landing instruction performed better on unassisted trials and on subjective ratings.

c. Author's Conclusions: Supplementary visual cues appeared to facilitate approach and landing performance in the simulator, at least when presented in the adaptive mode. Some adaptive augmented-feedback manipulations can be more effective than fixed-task methods for teaching perceptual-motor tasks with poor intrinsic feedback such as landing an airplane.

Within the limitations of the test that was undertaken, the simulator training had a strong and statistically reliable influence on the airplane landing work. It helped students on both frequency of unassisted landings and subjective ratings of performance by qualified flight instructors.

1. Author: Martin, Elizabeth L.

2. Title: Training Effectiveness of Platform Motion: Review of Motion Research Involving the Advanced Simulator for Pilot Training and the Simulator for Air-to-Air Combat

3. Source: AFHRL-TR-79-51, February 1981

4. Topic Keywords: Platform Motion ; Flight Simulation ; Motion Simulation ; Transfer of Training ; Training Effectiveness .

5. Short Summary: A review of six transfer-of- training studies involving the use of platform motion in the training simulator finds that the addition of task correlated platform motion cueing results in negligible transfer-of-training for initial jet piloting skills.

6. Devices:

   a. Advanced Simulator for Pilot Training (ASPT)

   b. Simulator for Air-to-Air Combat (SAAC)

7. Institutions:

   a. Sponsor: HQ Air Force Human Resources Laboratory (AFSC), Brooks AFB, TX 78235

   b. Performing Organization: Operations Training Division, Air Force Human Resources Laboratory, Williams AFB, AZ 85224

8. Type of Article: Six experiments are cited; Roman Numerals below follow text:

   I. STUDY I

      a. Number of Groups: 3

      b. Description of Groups:
         (1) Subjects: 8 Pre-flight Air Force UPT Students (simulator motion)
         (2) Subjects: 8 same (without simulator motion)
         (3) Controls: 8 same (without simulator training)

      c. Tests or Trials/Timing: In-process checkrides

      d. Number of Different Types of Measures: 2

e. Description of Measurements and Ratings:
(1) IP grades
(2) Automatic pilot performance data

f. Experimental Setting/Training Context: institutional, hands-on

g. Statistical Methods: not specified

h. Variables Being Manipulated:
(1) Training Devices: Advanced Simulator for Pilot Training
(2) Fidelity Levels:

	Physical	Functional
With Motion	High	Very High
No Motion	High	High

(3) Type of Task/Skill Required: operations, cognitive, psychomotor, perceptual, procedural, part-task, whole-task
(4) Task Difficulty: High

i. Stage of Training: introduction; skill

j. Trainee Sophistication: intermediate/novice

k. Incorporation of Device into P.O.I.: lock-step

l. User Acceptance or Attitude: not discussed

m. Use of Instructional Features: not discussed

II. STUDY II

a. Number of Groups: 3

b. Description of Groups:
(1) Subjects: 12 post-solo UPT students (with simulator motion
(2) Subjects: 12 same (without motion)
(3) Controls: 12 same (without simulator training)

c. Tests or Trials/Timing: In-process checkrides

d. Number of Different Types of Measures: 2

e. Description of Measurements and Ratings:
(1) IP overall grade
(2) IP grade per maneuver

f.-m. Same as for STUDY I, except for the following changes:

i. Stage of Training: Skill

j. Trainee Sophistication: Intermediate/high

III. STUDY III

a. Number of Groups: 4

b. Description of Groups:
(1) Subjects: 8 Pre-flight UPT students (motion/full field-of-view)
(2) Subjects: 8 same (motion/limited field-of-view)
(3) Subjects: 8 same (no motion/full F.O.V.)
(4) Subjects: 8 same (no motion/limited F.O.V.)
No Controls

c. Tests or Trials/Timing: post-checkride

d. Number of Different Types of Measures: 1

e. Description of Measurements and Ratings: IP Grade by task

f.-m. Same as for STUDY I, except for the following changes:

h. Variables being manipulated:
(1) Training Devices: Advanced Simulator for Pilot Training
(2) Fidelity Levels: Physical Functional

	Physical	Functional
Motion/Full FOV	High	Very High
Motion/Limited FOV	Med.-high	Very High
No Motion/Full FOV	High	High
No Motion/Limited FOV	Med.-high	High

IV. STUDY IV

a. Number of Groups: 2

b. Description of Groups:
(1) Subjects: 8 T-37 phase UPT students (with motion)
(2) Subjects: 8 same (without motion)

c. Tests or Trials/Timing: In-process trials

d. Number of Different Types of Measures: 1

e. Description of Measurements and Ratings: Time

to complete training by hours in simulator and aircraft

f. Experimental Setting/Training Context: institutional, hands-on

g. Statistical Methods: not specified

h. Variables Being Manipulated:
(1) Training Device: Advanced Simulator for Pilot Training
(2) Fidelity Levels:

	Physical	Functional
With Motion	High	Very High
No Motion	High	High

(3) Type of Task/Skill Required: operations, cognitive, psychomotor, perceptual, procedural, part-task, whole-task
(4) Task Difficulty: High

i. Stage of Training: Skill

j. Trainee Sophistication: Intermediate/High

k.-m. Same as for STUDY I

V. STUDY V

a. Number of Groups: 3

b. Description of Groups:
(1) Subjects: 8 Replacement Training Unit Students
(2) Subjects: 8 same
(3) Controls: 6 same

c. Tests or Trials/Timing: In-process checkrides

d. Number of Different Types of Measures: 2

e. Description of Measurements and Ratings:
(1) IP Overall grades
(2) IP grade by maneuver

f. Experimental Setting/Training Context: institutional, hands-on

g. Statistical Methods: not specified

h. Variables Being Manipulated:
(1) Training Devices: Simulator for

Air-to-Air Combat
(2) Fidelity Levels:

	Physical	Functional
With Motion	High	High
No Motion	High	Medium-High

(3) Type of Task/Skill Required: operations, cognitive, psychomotor, perceptual, procedural, part-task, whole-task
(4) Task Difficulty: High

i. Stage of Training: Skill; transition

j. Trainee Sophistication: High

k.-m. Same as for STUDY I

VI. STUDY VI

a. Number of Groups: 3

b. Description of Groups:
(1) Subjects: 8 Graduate student pilots with fighter lead-in training (with motion)
(2) Subjects: 8 same (without motion)
(3) Controls: 8 same (without simulator training)

c. Tests or Trials/Timing: Post-tests

d. Number of Different Types of Measures: 3

e. Description of Measurements and Ratings:
(1) Circular bombing error
(2) Number of qualifying bombs
(3) IP Grade

f. Experimental Setting/Training Context: institutional, hands-on

g. Statistical Methods: not specified

h. Variables Being Manipulated:
(1) Training Device: Advanced Simulator for Pilot Training
(2) Fidelity Levels:

	Physical	Functional
With Motion	High	Very High
No Motion	High	High

(3) Type of Task/Skill Required: operations, cognitive, psychomotor, perceptual,

procedural, part-task
(4) Task Difficulty: High

i. Stage of Training: Skill

j. Trainee Sophistication: Expert

k. Incorporation of Device into P.O.I.: Lock-step

l. User Acceptance or Attitude: not discussed

m. Use of Instructional Features: not discussed

9. Abstract:

a. Study Synopsis: This study reviewed five experiments performed with the Air Force Advanced Simulator for Pilot Training (ASPT) and one experiment performed with the Simulator for Air-to-Air Combat (SAAC), which measured the effects of simulated 6 degrees of freedom motion during training of jet pilots on transfer performance in the aircraft. Five of these experiments also had control groups who received no training in the advanced simulators, in order to determine the effectiveness of training in simulators regardless of motion. The studies are summarized as follows:

Study I (Basic Contact): Three groups of 8 pre- flight UPT students each were differently trained for basic contact maneuvers in T-37 jet trainer aircraft. Control group received standard syllabus with simulated pretraining in T-4 non-visual instrument trainer. Experimental groups received experimental syllabus training with the Advanced Simulator for Pilot Training, identical except that one group had platform motion in the ASPT, the other did not. Proficiency trials were two special T-37 checkflights during the course of training, plus task frequency data on all missions through solo sorties.

Results: No consistent differences were found between the transfer performances of the two (motion and no-motion) ASPT groups. The ASPT groups performed better in transfer than the control group.

Study II (Aerobatics): Three groups of 12 post-solo UPT students each were differently trained for flying aerobatics exercises in the T-37 jet trainer aircraft. Control group received standard syllabus training. Experimental groups received ASPT training in addition

to aircraft instruction; one group trained in the ASPT with motion, the other without. Performance was evaluated by instructor pilots both in aircraft and in the simulator, on specific parameter values per maneuver, and an overall rating.

Results: On transfer, the ASPT groups outperformed the control group in one maneuver. There were no differences between the ASPT groups trained with motion and without motion.

Study III (Motion/Visual Interaction): Four groups of 8 pre-flight UPT students each were differently trained in the ASPT for flying four basic tasks. Training treatments were as follows: (1) motion/full field of view; (2) motion/limited field of view; (3) no motion/full field of view; (4) no motion/limited field of view.

Results: No statistically reliable differences were observed between the groups in transfer performance in the aircraft.

Study IV (Motion vs. No-Motion in UPT Syllabus Study): Two groups of T-37 phase UPT students were differently trained in the ASPT during an experimental syllabus; one group with motion, the other without. Students were advanced on the basis of an IP's judgement of proficiency for the aircraft. The amount of time spent in simulator training to reach the IP-judged proficiency level was the measure of effectiveness.

Results: No significant differences in training time to reach proficiency appeared between the two groups.

Study V (Motion vs. No-Motion--Basic Fighter Maneuvering): Three groups of Replacement Training Unit students transitioning to the F-4 were differently trained; the Control Group of 6 received training in the SAAC, one with motion, one without. Students' performance in the F-4 aircraft was graded by Instructor Pilots.

Results: There were no significant differences between any of the groups in overall mission performance ratings in the aircraft, although the control group outperformed the SAAC-trained groups in some maneuvers.

Study VI (Motion vs. No-Motion--Air-to-Surface Weapons Delivery): Three groups of 8 graduate students with fighter lead-in experience each, were trained differently to perform dive bombing tasks in an F-5B

aircraft. The control group received no ASPT training; the two experimental groups received training on an ASPT configured as a T-37, one with motion, one without.

Results: The experimental ASPT-trained groups outperformed the control group in dive bombing runs in the aircraft; however, there were no differences between the performances of the Motion and No-Motion ASPT groups.

b. Results: Given on a per-study basis above.

c. Author's Conclusions: Simulator training generally led to better transfer performance with the exception of the Basic Fighter maneuvers taught in the SAAC; this exception indicated a failure of the specific training methodology. In the case of the bombing task experiment (Study VI), the superiority of the experimental groups, trained in a device which simulated a different aircraft from the transfer aircraft, indicated that effective transfer of training on this task did not require a maximum-fidelity simulator.

The author makes the following general conclusions:

(1) Platform motion has little or no demonstrated positive effect on transfer of training, at least for novice jet pilots acquiring basic contact skills.

(2) Platform motion has a small effect on the performance of experienced pilots in the simulator.

(3) Platform motion has the most potential for enhancing simulator training on specific tasks requiring control in a marginally stable condition.

Existing data do not support procurement of sophisticated six-post synergistic platform-motion systems for pilot contact skill acquisition; and existing simulators for pilot training possessing synergistic platform-motion systems can be equally effective if the motion system is not used.

Note: there is an error in the author's summary of experimental results in the beginning of the report (pp. 1-2): Experiments III and IV have been transposed.

Note: Studies I, III, and IV have been abstracted in more detail from the original reports elsewhere in this data

g. Statistical Methods: ANOVA; multiple regression analysis

h. Variables Being Manipulated:
(1) Training Devices: Modularized Synthetic Sonar Trainer
Experiment 1: various combinations of complexity, feedback and embeddedness
Experiment 2:
(a) Hot panel - dynamic mode
(b) Cold panel - inoperative mode
(c) Pictorial representation - photograph of panel

(2) Fidelity Levels:

	Physical	Functional
Experiment 1	varied Medium-High	varied Medium-high
Experiment 2		
HOT	High	High
COLD	High	Low
PICTORIAL	Medium-Low	Low

(3) Type of Task/Skill Required: operations, cognitive, psychomotor, perceptual, part-task
(4) Task Difficulty: varied Medium-Low to Medium-High on acquisition; Medium on transfer

i. Stage of Training: introduction, familiarization--not strictly applicable since this was experimental only

j. Trainee Sophistication: novice

k. Incorporation of Device into P.O.I.: lock-step

l. User Acceptance or Attitude: not discussed

m. Use of Instructional Features:
(1) Intensity: intensive
(2) Features used: not specified

9. Abstract:

a. Study Synopsis: This study concluded a three-phase series which sought to establish quantitative task indices for use in forecasting training device effectiveness. An earlier phase validated the relevance of certain task indices to acquisition; the present study was aimed at (1) applying a battery of these indices to transfer of training, and (2)

1. Authors: Mirabella, Angelo, & Wheaton, George R.

2. Title: Effects of Task Index Variations on Transfer of Training Criteria

3. Source: NAVTRAEQUIPCEN Technical Report 72-C-0126-1, January 1974

4. Topic Keywords: Quantitative Task Indices ; Transfer of Training ; Sonar Console Simulation .

5. Short Summary: The concluding study in a series aimed at establishing quantitative task indices to forecast training device effectiveness finds some practical value for the indices, and presents evidence for interaction between task indices and training methods involving different degrees of simulation fidelity.

6. Devices: Modularized synthetic sonar trainer with capability for changing modules between "simple" and "complex", for manipulating feedback and "embeddedness" of tasks.

7. Institutions:

   a. Sponsor: Naval Training Equipment Center, Orlando, FL 32813

   b. Performing Organization: Silver Spring, MD, American Institutes for Research ,

8. Type of Article: Experiment (Two)

   a. Number of Groups: Experiment 1: 20; Experiment 2: 18

   b. Description of Groups: For both experiments, each group consisted of 5 university-connected personnel from Washington, DC area; randomly assigned

   c. Tests or Trials/Timing: in-process trials; post-test for transfer

   d. Number of Different Types of Measures: 2

   e. Description of Measurements and Ratings:
      (1) Time to complete task
      (2) Errors on task

   f. Experimental Setting/Training Context: laboratory, hands-on

the simulation group.

The students' evaluations of their improvement showed no difference between groups.

c. Authors' Conclusions: Simulators seem an inefficient way simply to communicate safety information. Any difference between the two groups on the knowledge test can be attributed to differential emphasis upon simulator and lecture subjects... that occurred despite our efforts to equalize them.

The same may well hold true for attitudes.

Potential for effective simulated driver training lies in the capability of the simulator to complete a stimulus-response connection. What is needed to exploit the full capabilities of simulation is (1) far greater practice on responses to be acquired; (2) periodic retesting to sustain response tendencies at a high level; and (3) research to determine appropriate emergency responses as well as the limits of effective stimulus and response generalization.

(2) Fidelity Levels: not specified; presumably low
(3) Type of Task/Skill Required: automobile driving; cognitive; psychomotor
(4) Task Difficulty: Low

i. Stage of Training: Refresher

j. Trainee Sophistication: Intermediate/Expert (all were experienced drivers)

k. Incorporation of Device into P.O.I.: lock-step

l. User Acceptance or Attitude: not specified

m. Use of Instructional Features: not specified

9. Abstract:

a. Study Synopsis: The purpose of the study was to evaluate the comparative effectiveness of a simulator in teaching safe driving knowledge and habits, versus conventional driver training media. Twelve classes, totaling 238 enlisted men, were administered a 20-hour driver improvement program. Half of the classes received eight hours of simulator instruction while the remaining half received the same content taught by conventional media including films, and group discussions.

Driving knowledges were measured after the training by a 50-item multiple choice test covering both simulator and lecture material. Also, a test drive on the simulator was given to all subjects and controls; controls were given familiarization with the device prior to testing. (Note: the reviewer infers that a test drive was the second test medium; the authors never said so explicitly).

Students also made a self-evaluation of their own improvement during the course.

b. Results: The knowledge test revealed no truly significant differences. Whatever differences exist (at the .10 to .15 level), favor the simulator group for covered in the simulator program, the conventional group for lecture material.

The results for driving habits paralleled the emphasis given to them in the simulator programs. Those that were practiced most often... showed differences of both statistical and practical significance in favor of

1. Authors: McKnight, A. James, & Hunter, Harold G.

2. Title: An Experimental Evaluation of a Driver Simulator for Safety Training

3. Source: HumRRO Professional Paper 9-66, December 1966

4. Topic Keywords: Stimulus-Response Connection ; Generalization Gradients ; Simulation ; Training Effectiveness .

5. Short Summary: Initial studies of the use of simulators in automobile driver training conclude that then- existing moving-picture driving simulators do not merit full scale long-term study until more research is done on the limits of effective stimulus-response generalization.

6. Device: Motion-picture automobile driving simulator

7. Institutions:

a. Sponsor: U.S. Continental Army Command

b. Performing Organization: HumRRO Division No. 1, Alexandria, VA

8. Type of Article: Experiment

a. Number of Groups: 12

b. Description of Groups:
(1)-(6) Subjects: Approximately 14 each group, enlisted military personnel holding driver's licenses
(7)-(12) Controls: Same

c. Tests or Trials/Timing: 2 post-tests (up to 2 1/2 mo.s after training)

d. Number of Different Types of Measures: 2

e. Description of Measurements and Ratings:
(1) Multiple-choice knowledge questions
(2) Test drive in simulator (reviewer's inference)

f. Experimental Setting/Training Context: experiment at military base; driver's education program

g. Statistical Methods: not specified

h. Variables Being Manipulated:
(1) Training Device: as above, section 6

experimental subjects and controls, except that in the device-training portion of the radar maintenance block, the subjects were trained on the ECII only, the controls on the AET only. Subjects numbered 15 and controls, 24, with the controls having more prior experience with radar maintenance (how much more was not specified). Two immediate post-tests were given to subjects and controls after the radar maintenance block: a normal-system- operation checklist and a set of eight simple malfunction troubleshooting problems.

b. Results:

(1) Key Data: 2 of 39 students failed to reach criterion performance (both groups combined).

Mean score: 90.5 out of 95 checklist items (both groups combined)

(2) Verbal Description: No significant differences were found between simulator-trained subjects and actual- equipment-trained controls on the post-tests.

Questionnaires given to instructors and students found the simulator generally acceptable to both; although those instructors who had not participated in the development of the simulator were cautious in recommending it (they had less knowledge of its capabilities). "In the course of evaluating the students on the normal operations checkout, the instructors felt that those students trained on the simulator exhibited a more logical or rational approach to the checkout procedure."

c. Authors' Conclusions: The ECII was found at least equally as effective as the AET in training the selected radar maintenance skills in a refresher course. The students trained on the simulator (those with little or no previous related experience) performed as well as those training on the trainer (those with previous radar system experience).

Evidence from instructor comments suggests that perhaps the unique training capabilities of the simulator enable the student to adopt a more appropriate "cognitive style" for this kind of task.

f. Experimental Setting/Training Context: Institutional, hands-on

g. Statistical Methods: Not specified

h. Variables Being Manipulated:
(1) Training Devices:
(a) ECII computerized multiply-programmable simulator
(b) Actual Equipment Trainer, modified for training
(2) Fidelity Levels:
(a) Physical: ECII, Low-Medium; AET, High
(b) Functional: ECII, High; AET, High
(3) Type of Task/Skill Required: maintenance, cognitive, procedural
(4) Task Difficulty: Medium

i. Stage of Training: Refresher

j. Trainee Sophistication: Intermediate to high

k. Incorporation of Device into P.O.I.: lock-step

l. User Acceptance or Attitude:
(1) Instructors: fair, as assessed by questionnaire
(2) Students: noncommittal

m. Use of Instructional Features:
(1) Intensity: unspecified; probably incomplete
(2) Features used: freeze capability, restart/resequence capability; malfunction selection; number/quality of responses; probably cue enchancement features; others not specified

9. Abstract:

a. Study Synopsis: The study was designed to compare the effectiveness of the ECII computerized multiply-programmable equipment with that of the Actual Equipment Trainer then in standard use in a refresher maintenance training course for Air Force and Air National Guard personnel. The ECII, while of considerably lower physical fidelity than the AET, had a number of instructional features not available on the AET. A cost analysis of the two devices was also part of this study, which found that developing and procuring the simulator was much less expensive than procuring an AET.

The standard training syllabus was used for both

1. Authors: McGuirk, Frank D., & Pieper, William J.

2. Title: Operational Tryout of a General Purpose Simulator

3. Source: AFHRL-TR-73-13, May 1975

4. Topic Keywords: Troubleshooting Maintenance Training ; General Purpose Simulator .

5. Short Summary: Comparison of a General Purpose Maintenance Training Simulator, ECII (a computerized multiply- programmable training device) with an Actual Equipment Trainer modified slightly for training, showed the General Purpose Simulator at least equally effective in training students in radar maintenance tasks, at a fraction of the cost.

6. Devices: ECII computerized multiply-programmable maintenance Training Simulator; and Actual Equipment Trainer, field equipment slightly modified for training purposes

7. Institutions:

   a. Sponsor: HQ Air Force Human Resources Laboratory , Brooks AFB, TX 78235

   b. Performing Organization: Applied Science Associates, Inc., Box 158, Valencia, PA 16059

8. Type of Article: Experiment

   a. Number of Groups: 2

   b. Description of Groups:
      (1) Subjects: 15 airmen undergoing retraining (to be trained on simulator)
      (2) Controls: 24 same but with more prior radar maintenance experience (to be trained on Actual Equipment Trainer)

   c. Tests or Trials/Timing: Two post-tests

   d. Number of Different Types of Measures: 2

   e. Description of Measurements and Ratings:
      (1) Procedures Checklist
      (2) Malfunction Problem-solving
         (a) No. of trials to solution
         (b) Time to solution

measures were criterion-referenced, not merely control input derivations, and so may not be the most sensitive to motion-cue manipulations; (4) with the exception of stalls, motion cues were not training-relevant cues for the tasks covered in this study; and (5) the subjects were student pilots with no previous jet flying experience, while theoretically, motion cues acquired meaning as a function of experience. For whatever reason, motion cueing was not a potent training variable. The data failed to demonstrate any enchancement of training effectiveness as a result of the addition of platform motion.

IP Ratings

Straight & Level	M	8.08	9.63	9.53	10.13	
	NM	8.86	9.00	8.98	8.25	
CAS Climb	M	6.86	7.72	9.13		
	NM	7.36	7.87	8.50		
Steep Turn	M	5.57	6.43	5.70	4.25	
	NM	5.50	6.13	5.55	5.75	
Takeoff	M	5.23	6.88	6.25	6.98	
	NM	5.75	6.63	4.88	7.25	
Straight in Approach	M	4.10	7.13	5.95	6.75	
	NM	4.78	7.49	5.03	5.13	
Overhead Pattern	M	3.00	3.59	4.88	5.88	6.01
	NM	3.38	5.00	6.00	6.56	6.00

(2) Verbal Desctription:

(a) On 10 ASPT mission profiles (experimental subjects only), there were not significant differences between the motion and no-motion conditions for any of the maneuvers using either the automated performance measures or the Instructor Pilot ratings.

(b) On T-37 aircraft training transfer evaluations by checkflight, there were not significant differences between the motion and no-motion simulator training groups as derived from inprocess data rides on aircraft; whereas, the performance of the ASPT-trained groups combined was superior to the control groups across all maneuvers (utilizing a prior "t" tests), as determined from task frequency data on checkflight.

c. Authors' Conclusions: The motion variable did not have significant beneficial training value in either the simulator training phase of the aircraft training phase.

There are several experimental design factors which may have contributed to these findings: (1) small sample size--8 per group; (2) the between- and within-subject variability was high, and there were uncontrolled factors which acted to increase variance, e.g., weather conditions, etc., on sorties; (3) the dependent

which quantitative data were obtained as well as Instructor Pilot ratings, and received two special data flights on the aircraft; both subjects and controls received post-experiment performance checkflights ("pre-solo syllabus sorties"), where task frequency data were recorded by Instructor Pilots.

Results established the training value of the Advanced Simulator for Pilot Training, for the simulator-trained pilots outperformed the aircraft-trained pilots in the aircraft checkflight, although it is important to remember that the simulator-trained students had already received two special data flights on the aircraft prior to taking the checkflight. The data failed to reveal any significant difference between the two simulator-trained groups in performance on either simulator or aircraft, indicating that at least for this level of experience, the addition of platform motion in simulated training did not enhance learning.

b. Results:

(1) Key Data:

Descriptive Statistics for ASPT Performance Evaluations

APM Scores

Maneuver		Trial 1	2	3	4	5
Straight & Level	M	59.51	48.23	45.59	43.63	
	NM	53.04	50.06	48.86	51.09	
CAS Climb	M	59.88	46.93	44.45		
	NM	52.29	50.93	45.52		
Steep Turn	M	51.91	48.88	47.26	50.74	
	NM	53.79	48.38	49.69	49.36	
Takeoff	M	49.48	49.39	47.92	46.17	
	NM	53.21	51.59	56.77	45.46	
Straight-in Approach	M	49.96	44.81	49.77	50.75	
	NM	53.29	45.78	53.80	51.84	
Overhead Pattern	M	55.21	49.25	48.93	47.07	48.61
	NM	53.47	49.44	51.03	47.61	49.36

and controls, on checkflights; for subjects, on ASPT mission profiles)

f. Experimental Setting/Training Context: Institutional, hands-on

g. Statistical Methods: ANOVA; t-test

h. Variables Being Manipulated:
(1) Training Devices: Advanced Simulator for Pilot Training (ASPT)
(a) With 6 DOF platform motion
(b) No platform motion
(2) Fidelity Levels:
(a) Physical: High
(b) Functional: High; higher for device with motion
(3) Type of Task Required: Jet aircraft flight; operations
(4) Task Difficulty: High
(5) Skills required by task: motor; perceptual; cognitive

i. Stage of Training: Introduction; familiarization; skill

j. Trainee Sophistication: Novice and intermediate

k. Incorporation of Device into P.O.I.: lock-step

l. User Acceptance or Attitude:
(1) Instructors: unspecified
(2) Students: unspecified

m. Use of Instructional Features: Intensive

9. Abstract:

a. Study Synopsis: A transfer-of-training experiment was designed to evaluate the contributions of simulated motion to training on a high fidelity aircraft flight simulator. A synergistic 6-degree-of-freedom platform motion system was used in the training of basic jet aircraft contact, approach, and landing skills. 24 pilot trainees with no jet flight experience and a mean of 28.8 hours pilot experience overall were divided into three training groups of 8 members each: (1) received training on simulator with motion; (2) received training on simulator without motion; (3) received training only on aircraft (control group). The simulator-trained groups received 10 instructional sorties in the simulator on basic contact tasks, for

1. Authors: Martin, Elizabeth L., & Waag, Wayne L.

2. Title: Contributions of Platform Motion to Simulator Training Effectiveness; Study 1 - Basic Contact

3. Source: Technical Report: AFHRL-TR-78-15, June 1978

4. Topic Keywords: Transfer of Training ; Flight Simulation ; Platform Motion ; Training Effectiveness .

5. Short Summary: A transfer of training study shows no significant differences between test performances (including real aircraft flight) of jet aircraft flight trainees trained on simulators with kinesthetic and vestibular clues and those trained on the same device without kinesthetic and vestibular clues. However, on advanced flight tasks, both groups out-performed a control group that received all its training on the aircraft.

6. Devices: Advanced Simulator for Pilot Training (ASPT)

7. Institutions:

a. Sponsor: Hq Air Force Human Resources Laboratory (AFSC), Brooks Air Force Base, TX 78235

b. Performing Organization: Flying Training Division, Air Force Human Resources Laboratory, Williams Air Force Base, AZ 85224

8. Type of Article: Experiment

a. Number of Groups: 3

b. Description of Groups:
(1) Subjects: (ASPT trained, with motion): 8 undergraduate pilot training students, minimal flying experience
(2) Controls: 8 same
(3) Subjects: (ASPT trained, no motion): 8 same

c. Tests or Trials/Timing: 10 process tests on simulator (experimental subjects only); 2 process tests on aircraft; 1 post-test on aircraft

d. Number of Different Types of Measures: 2

e. Description of Measurements and Ratings:
(1) Automated Performance Measures (with-subject only, on simulator; for 10-in process trials)
(2) Instructor Pilot ratings (for both subjects

base: Martin & Waag, June 1978; Nataupski, et al., November 1979; and Woodruff, et al., December 1976, respectively.

examining the effects of interaction between task characteristic measured by the indices, and training methods, specifically simulation fidelity.

Two experiments were conducted using a modularized synthetic sonar trainer. Modularization of the simulator enabled the experiments to vary task complexity, among of feedback, and the "embeddedness" of the task within the console as a whole. In both experiments, all training and testing were conducted on the simulator. In the first experiment, subjects were trained in groups of 5, on one of the 20 tasks which differed over a wide range of task index values, and in levels of feedback and embeddedness; subjects were all tested for transfer on one task of medium complexity. In the second experiment, three levels of fidelity were employed in the simulator during training: (1) "hot" panel, high physical and high functional fidelity; (2) "cold" panel (did not operate), high physical but low functional fidelity; and (3) "pictorial representation," a photograph of the console, medium-low physical fidelity and low functional fidelity.

The performances on training and transfer trials were measured in terms of time to complete tasks, and number of errors.

b. Results: EXPERIMENT 1

(1) Key Data:

Multiple Regression Analyses Using Difference Scores to Predict Raw Time and Error Scores for First, Middle, and Last Block of Transfer Trials

Criterion	R	R2	df	F	
		Time Scores			
Transfer Trials 1-2 (First Block)	.751	.564	3, 11	4.75	'
Transfer Trials 5-6 (Middle Block)	.771	.595	3, 11	5.39	'
Transfer Trials 9-10 (Last Block)	.805	.648	3, 11	6.76	*
		Error Scores			
Transfer Trials 1-2	.890	.793	3, 11	14.03	**
Transfer Trials 5-6	.914	.836	3, 11	18.67	**
Transfer Trials 9-10	.824	.679	3, 11	7.75	*

Indices represent absolute differences between acquisition and transfer tasks.

' p. < .025.
* p. < .01.
** p. < .001.

R = Multiple correlation coefficient
R2 = Percentage of variance in criterion accounted for
df = Degrees of freedom used in testing significance of R
F = Resultant F value

(2) Verbal Description:

(a) Acquisition: The main effects of complexity, feedback embeddedness, and trials were all found to influence acquisition performance, as expected. There was a significant interaction between task complexity and trial block. The initial differences in error rate due to various levels of complexity, although maintained across trails, decreased as training continued. A greater

average number of errors resultes from removal of feedback, even though fewer responses are required in such tasks, although the interaction with task complexity was not significant. As the level of embedding increases, errors become a function of increasing levels of feedback; conversely, as the percentage of distracting stimuli decreased, increasing errors were associated with decreasing feedback. Feedback had a simpler and more systematic effect on performance time; the results suggest that tasks consisting of more responses take relatively longer to perform than tasks consisting of fewer responses.

In general, even when the effect upon performance time due to the number of responses is removed, significant multiple correlations between task indices and time are still obtained at all three acquisition stages.

(b) Transfer: The main effects of complexity, feedback and trial block were found to impact upon transfer performance as expected. Transfer from the more complex device is better than transfer from the less complex device, given that the critical feature of feedback is present. Presence or absence of feedback during training has its most marked effect on transfer for complex tasks, its smallest effect for simple tasks, and an intermediate effect for the medium task. These differences tend to dimish over trial block, although they are not still prevelent on the last transfer trials.

As shown in the table above, significant multiple correlations are obtained between task indices and both time and error measures at each stage of transfe.r The differences between acquisition and transfer tasks in the number of displays, the percentage of controls used, and the weighted Display Evaluative Index bear strong relationships to the criterion at each point.

Results: EXPERIMENT 2

Acquisition: The impact of task complexity on acquisition criteria was similar to that reported earlier for the transfer of training study.

There is evidence that training method affects the number of errors made during acqusition. The most errors occur when the cold panel method is used.

The hot-panel and pictorial methods are comparable. Errors as a function of the interaction between task complexity and training method approached significance, tending to indicate that the relative inferiority of the cold panel approach holds only for the complex task situation. Performance time was not influenced by method during acquisition.

Transfer: Training task complexity had a parallel effect on transfer performance to that in Experiment 1; significantly fewer errors occured following training on a more complex task than on a simpler one. Time scores during transfer were a function of an interaction between acquisition task complexity and trial block.

Training method consistently interacted with trails to determine performance during transfer. A significant training method by trials interaction is shown. The relative superiority of training on the hot panel early in transfer decreases over time, in number of errors. By the end of the transfer period, the three methods are virtually the same in terms of error rates. A significant training method- by-trial interaction for transfer performance time was found for the simple task. The difference in performance time is maintained across the entire transfer period between the hot panel and cold panel groups, while the pictorial group, after an initial retardation relative to the hot panel group, rapidly converges with it.

c. Authors' Conclusions: Consistently large and intuitively systematic variations in performance were obtained as a function of task/trainer configuration. The predictive power of the indices for skill acquisition was upheld, with multiple correlations substantially the same as found in Phase II. The pattern of predictors changes somewhat in Phase III; for example, the Display Evaluative Index entered prominently in Phase III among the predictors of both time and error scores; it did not appear at all in Phase II analyses. The pattern of predictors was shown to vary across criterion mesures and across time blocks within criterion measures during acquisition. Thus, a simple figure-of-merit approach to device evaluation was not supported in terms of acquisition performance. The transfer data, however, show greater consistency, and provide greater encouragement for a figure-of-merit approach when transfer of training criteria was

employed.

The current results provide an instance in which it was possible to quantify similarity for a surrogate "real world" task and to predict performance with very high validity. High validity was obtained notwithstanding an interaction between task complexity and feedback.

The results of Experiment 2 provide some support for the hypothesis of an interaction between task parameters and method of training. During acquisition, training method appeared to have a differential effect for the complex task, with cold panel generating more errors than either pictorial or hot panel. In the transfer data, presence or absence of task embeddedness generated a differential performance effect for training methods. Dynamic presentation led to consistently faster performance across transfer blocks than either cold or pictorial presentation. Its superiority was greater under the no-embedding condition. Otherwise, the results were consistent with those of earlier studies. An initial advantage of dynamic training, upon transfer, rapidly dissipated--particularly in regard to the pictorial methods.

At this level, the indices could be employed as one of several tools to support the training expert's evaluation of alternative prototype devices--for example, to corroborate or question judgements already established by other means. More rigousous and confident use, however, requires cross validation on actual training devices.

1. Authors: Nataupsky, Mark, Waag, Wayne L., Weyer, Douglas D., McFadden, Robert W., & McDowell, Edward

2. Title: Platform Motions Contributions Simulator Effectiveness; Study III - Interaction of Motion with Field-of-View

3. Source: AFHRL-TR-79-25, November 1979

4. Topic Keywords: Flight simulation ; Motion simulation ; Motion cues ; Field-of-view ; Platform motion ; Transfer of training . 5. Short Summary: A transfer of training study of the interaction between flight simulator motion cuing and simulated field-of-view finds no significant interaction between the two. Furthermore, no enhancement of transferred skills due to platform motion itself, was found in the training of flight-naive undergraduate pilot students to fly the T-37 jet trainer.

6. Devices:

a. T-37 jet trainer (test device only)

b. Advanced Simulator for Pilot Training

7. Institutions:

a. Sponsor: HQ Air Force Human Resources Laboratory (AFSC), Brooks Air Force Base, TX 78235

b. Performing Organization: Flying Training Division, AFHRL, Williams Air Force Base, AZ 85224

8. Experiment:

a. Number of Groups: 4

b. Description of Groups: Subjects - each group approximately 8 student jet pilots, range of previous flight experience 25-64 hours

c. Tests or Trials/Timing: In-process trials; 1 post test (checkflight)

d. Number of Different Types of Measures: 3

e. Description of Measurements and Ratings:
(1) Instructor pilot-scored special data card ratings (simulator and aircraft)
(2) Quantified data from simulator's recording instruments

(3) Instructor checkflight ratings

f. Experimental Setting/Training Context: Institutional, hands-on

g. Statistical Methods: ANOVA

h. Variables Being Manipulated:
(1) Training Devices: as above, section 6
Four conditions for ASPT training:
(a) full platform motion with full field-of-view (FOV)
(b) full platform motion with limited field-of-view
(c) no platform motion, full field-of-view
(d) no platform motion, limited field-of-view
(2) Fidelity Levels:

	Physical	Functional
Motion, full FOV	High	High
Motion, Limited FOV	Med. High	High
No Motion, full FOV	High	Med. High
No Motion, Limited FOV	Med. High	Med. High

(3) Type of Task/Skill Required: aircraft pilot operations; cognitive; psychomotor; perceptual; part-task
(4) Task Difficulty: Medium high

i. Stage of Training: introduction; familiarization; skill; transition

j. Trainee Sophistication: novice

k. Incorporation of Device into POI: lock-step

l. User Acceptance or Attitude: not discussed

m. Use of Instructional Features:
(1) Intensity: intensive
(2) Features used: freeze capability; restart/resequence capability; number/quality of responses; record/playback

9. Abstract:

a. Study Synopsis: This study was designed to determine the effects of motion cueing, field-of-view, and their interaction, on (1) skill acquisition in a flight simulator and (2) transfer of learning to aircraft, in undergraduate jet pilot trainees with little prior flying experience.

The device used for training was the Advanced Simulator for Pilot Training, a high-fidelity full mission instrument and visual flight simulator capable of full field-of-view (FOV) with great visual detail, and of platform motion that provides translational and rotational onset cues to the student pilots with between 25 and 64 hours prior flying experience. They were divided into four groups of approximately 8 each and separately trained on specific, uniform maneuvers in the simulator under four different conditions: (1) full platform motion with full FOV; (2) full platform motion with limited FOV; (3) no platform motion with full FOV and (4) no platform motion with limited FOV. Subjects were subsequently tested for transfer to a T-37 jet training aircraft on one sortie, and scored on the same maneuvers they had run in the simulator. Measures taken in the simulator were instructor ratings and quantified data from the simulator recording instruments; measures on the aircraft were instructor ratings.

b. Results:

(1) Key Data: Mean T-37 Evaluation Data (Instructor Pilot Ratings)

Task	Motion		FOV		Motion-on		Motion-off	
	On	Off	full	lim.	full	lim.	full	lim.
Takeoff	3.88	2.56	3.00	3.44	3.75	4.00	2.25	2.88
Steep Turn	3.06	1.93	2.50	2.53	3.50	2.63	1.50	2.43
Slow Turn	3.32	2.27	2.94	2.67	3.63	3.00	2.25	2.29
Straight-In	2.44	1.93	2.00	2.43	2.38	2.50	1.63	2.33

(2) Verbal Description: There is little evidence that motion, field-of-view, or their interaction significantly affected skill acquisition in the simulator.

Significant performance differences did occur, however, among the groups during simulator training for the motion factor. For certain measures, the measured trial, including the first; although the underlying reason is unclear.

For transfer of training data collected in the aircraft, neither motion, field-of-view, not their interaction during simulator training differentially affected performance as measured by instructor ratings. There was a trend toward better performance by the motion-trained groups. Of the 58 statistical tests computed on the aircraft evaluation data, only three produced significant effects. The extent to which these

represent real effects is unknown, since the provability of significant differences given the number of tests is quite high.

Due to Air Training Command rules, this study could not include a control group, but there are good reasons to assume the transfer of learning did occur.

c. Authors' Conclusions: These data provide support for previous findings that platform motion cueing does not significantly enhance the transfer of learning for basic contact tasks in the T-37 aircraft.

It would seem that the impact of peripheral visual cues for initial acquisition is not critical; furthermore, no convincing evidence was found indicating increased transfer using platform motion in conjunction with a narrow field-of-view.

It seems reasonable to conclude that no substantial or practical differences in training effectiveness resulted from manipulation of platform motion cueing and the field-of-view of the visual scene.

1. Authors: Pohlmann, Lawrence D, & Reed, John C.

2. Title: Air-to-Air Combat Skills: Contribution of Platform Motion to Initial Training

3. Source: AFHRL-TR-78-53, October 1978

4. Topic Keywords: Flight Simulation ; Motion Cues ; Air Combat Maneuvering ; Transfer of Training ; Training Effectiveness .

5. Short Summary: No significant differences in performance in real aircraft combat training was found between student pilots who had received simulated combat training prior to aircraft flight, and those who had not.

6. Devices:

a. F-4 fighter (test device only)

b. Simulator for Air-to-Air Combat: high fidelity combat flight simulator
(1) With 6 degrees of freedom platform motion
(2) Without motion

7. Institutions:

a. Sponsor: HQ Air Force Human Resouices Laboratory (AFSC), Brooks AFB, TX 78235

b. Performing Organization: Flying Training Division, AFHRL, Williams AFB, AZ 85224

8. Type of Article: Experiment

a. Number of Groups: 3

b. Description of Groups:

(1) Subjects: 8 military F-4 pilot students matched by past performance--trained in simulator without motion
(2) Subjects: 8 same, trained in simulator with platform motion
(3) Controls: 8 same, received no simulator training

c. Tests or trials/timing: In-process trials; 4 post-test (real aircraft checkflights)

d. Number of different types of measures: 2

e. Description of measurements and ratings:
(1) Instructor grading for each trial of each maneuver
(2) Instructor grading overall for each measure

f. Experimental setting/training context: institutional, hands-on

g. Statistical methods: one-way ANOVA

h. Variables being manipulated:
(1) Training devices: as above, section 6
(2) Fidelity Levels:

	Physical	Functional
With Motion	High	High
No Motion	High	Medium-High

(3) Type of task/skill required: aircraft combat piloting; operations, cognitive, psychomotor, perceptual, part-task
(4) Task difficulty: high

i. Stage of training: familiarization, skill, transition

j. Trainee sophistication: intermediate

k. Incorporation of device into P.O.I.: lock-step

l. User acceptance or attitude:
(1) Instructors: good for their own use; doubtful of device suitability for students
(2) Students: positive

m. Use of Instructional Features:
(1) Intensity: intensive
(2) Features used: freeze capability; restart/resequence capability; record/playback very rarely (feature not reliable); others not specified

9. Abstract:

a. Study Synopsis: This study was designed to determine the training effectiveness of the Simulator for Air-to-Air Combat (SAAC) in teaching skills to student pilots in the initial combat phase of training, as well as to determine of 6-degrees-of-freedom platform motion contributed to learning in the SAAC. Two groups of 8 students pilots each were trained in the SAAC, one with motion, one without motion. A

third, control group, received no simulator training. The three groups were subsequently tested for transfer in four real-aircraft missions. Instructors graded students on the execution of 10 Basic Fighting Maneuvers and on 9 discrete skills (e.g., "Range Estimation", "Attitude"), both in the simulator and in the aircraft.

Both students and instructors also completed questionnaires on their simulator training.

Limitations of the simulated training in this experiment were noted: (1) the record/playback feature of the SAAC was very rarely used--it was unreliable and scheduled for upgrading; (2) the problem freeze feature was rarely used due to instructor reluctance; (3) in general, instructors were reluctant to use any device feature other than reset.

A further technical impediment to training inherent in the simulator design was that instructors "flew" the simulated missions from the cockpit of the adversary aircraft; this reduced communication between instructor and student.

b. Results:

(1) Key Data:

Mean Performance Ratings for Maneuvers

Phase	No-SAAC	No-Motion	Motion	p
Initial Simulator	-	3.94	3.93	.96
Final Simulator	-	4.85	5.45	.03
Initial Aircraft	4.03	3.73	3.64	.29
Final Aircraft	4.89	4.56	4.47	.06
Overall Aircraft	4.44	4.20	4.13	.12

Mean Performance Ratings for Skills

	No-SAAC	No-Motion	Motion	p
Initial Simulator	-	5.65	5.02	.05
Final Simulator	-	5.58	6.49	.01
Initial Aircraft	5.17	4.79	4.96	.50
Final Aircraft	5.22	5.24	5.19	.98
Overall Aircraft	4.98	5.12	5.12	.79

(2) Verbal description: It was found that learning took place in the simulator and in the aircraft for all groups. However, the students trained in the SAAC did not perform better in the aircraft than those who had received no simulator

training--if anything, the statistically nonsignificant edge went to the no-simulator group (tables above). The only significant differences were between the motion and no-motion groups during simulator training, with the motion group scoring better on final simulator maneuvers, and on initial and final simulator skills--but their superiority did not transfer to real-aircraft performance.

On questionnaires, students' consensus was that SAAC training helped them initially to picture maneuvers better in the aircraft; but there was no consensus as to whether it helped them perform better. Instructors generally agreed, subjectively, that they saw no difference between simulator- trained students and non-simulator-trained students in the aircraft.

c. Authors' Conclusions: The data did not reflect any noticeable increment of effectiveness due to platform motion. There were no consistent transfer of training differences between the motion and no-motion groups.

If anything, there is some indication that the students who did not receive SAAC training performed better in the aircraft.

The reader should keep in mind the integral relationship of training program and training device.

There are several explanations for the lack of significant aircraft performance differences between groups:

(1) Instructor ratings may not have been sufficiently sensitive or consistent
(2) "Performance" grades may not be measuring the kind of conceptual knowledge derived from the simulator.
(3) The fact that simulator training in this study was an additional activity, over and above other schooling, may have impaired its effectiveness.
(4) Device design, with the instructor in a removed cockpit (the adversary aircraft) may not be suited to the initial phase of learning combat maneuvers--this was a majority opinion of instructors.
(5) Important instructional features of the device were not used, or rarely used, because of the reluctance of instructors and, in the case of the playback feature, because the equipment was unreliable and due for upgrading.

The results of the current experiment leave the question of the need for platform motion for training air-to-air combat tasks unanswered.

f. Experimental Setting/Training Context: Institutional, hands-on

g. Statistical Methods: Chi Square

h. Variables Being Manipulated:
  (1) Training Devices: Ground based flight simulators, Link AN-T-18 and GAT-1
  (2) Fidelity Levels:
    (a) Physical: unspecified, presumably medium high to high for both
    (b) Functional: presumably high for GAT-1, medium- high for Link AN-T-18
  (3) Type of Task: Operations (flight)
  (4) Task Difficulty: High
  (5) Skills required by task: motor, perceptual, cognitive

i. Stage of Training: Familiarization and Skill

j. Trainee Sophistication: Novice

k. Incorporation of Device into P.O.I.: Instructor-managed individually

l. User Acceptance or Attitude:
  (1) Instructors: Good
  (2) Students: Not discussed

m. Use of Instructional Features: Intensive

9. Abstract:

a. Study Synopsis: The relative benefits of different types of flight training equipment were evaluated in a routine instructional situation with no particular constraints placed upon the instructors as to how they used the equipment, and without interfering with the normal course of flight training. The objectives of this research were:
  (1) to determine the relative training value of 11 hours flight instruction in two different ground trainers, as compared with in the aircraft;
  (2) to evaluate the flight instructors' ability to predict success in private pilot training on the basis of students' initial performance in each of two ground trainers as opposed to actual aircraft;
  (3) to develop an objective scale for checking flight proficiency.

The ground trainer groups passed their flight checks with an average of slightly more than an hour greater

1. Authors: Povenmire, H. Kingsley, & Roscoe, Stanley N.

2. Title: An Evaluation of Ground-Based Flight Trainers in Routine Primary Flight Training

3. Source: Human Factors , 1971, 13(2), 109-116

4. Topic Keywords: Flight Training ; Transfer Effectiveness ; Ground-based Simulator ; Transfer Effectiveness Ratio .

5. Short Summary: Ground-based simulated flight training can be equally as effective as aircraft flight training up to some cut-off point in time that may be indicated with a simple "Transfer Effectiveness Ratio".

6. Devices: Ground-based flight simulators:

   a. Link AN-T-18 medium-high fidelity

   b. GAT-1 general aviation trainer high fidelity

7. Institutions:

   a. Sponsor: Link Foundation

   b. Performing Organization: Aviation Research Laboratory, Institute of Aviation, University of Illinois , Savoy, IL 61874

8. Type of Article: Experiment

   a. Number of Groups: 3

   b. Description of Groups:
      (1) Controls: 11 aviation college students without previous flight experience
      (2) Subjects: 13 same
      (3) Subjects: 12 same

   c. Measures and Timing of Measures: Pre-evaluation, and post-tests

   d. Number of Different Types of Measures: 3

   e. Description of Measurements and Ratings:
      (1) Pre-evaluation: instructor prediction of performance
      (2) Post-test: score on final check flight
      (3) Amount of training time required to reach final check flight

trainer--therefore, cockpit procedures trainers should be used prior to aircraft training if maximum benefit is to be derived from their use; (5) there is substantial task identity between ground cockpit procedures in the aircraft and in the two simulation devices studied.

device-trained groups. Both groups reached an asymptotic curve of error-reduction at the same rate when tested in the actual aircraft. Moreover, the device-trained groups took less training time to criterion than did the aircraft-trained group.

Emergency procedures were not covered in this study, because neither simulator was deemed to approach the stress and time-sharing loads that exist in a real aircraft emergency.

This study appears to confirm that task fidelity, which in many cases can be achieved in a simulator of low physical fidelity, is as important as or more important than physical fidelity in the acquisition and transfer of procedural skills

b. Results:

(1) Key Data:

MEAN PERCENTAGE OF ERROR ON AIRCRAFT (TRANSFER) TRIALS BY TRAINING CONDITION

TRAINING CONDITION

	Aircraft(N=10)	2-C-9(N=10)	Mockup(N=10)
Trial 1	19.6	6.1	6.3
Trial 2	11.6	4.8	3.7
Trial 3	7.2	2.9	2.7
Trial 4	5.5	3.2	2.1
Trial 5	4.3	3.8	3.7
Trial 6	2.3	no trial	no trial

(2) Verbal Description: Lower error rates for trainer groups than for aircraft-trained group significant at $p < .001$. Differences between two trainer groups not significant.

c. Authors' Conclusions:
(1) The 2-C-9 trainer (high fidelity) is an effective device for teaching pre-start, start, run-up, and shut-down procedures for the OV-1 aircraft;
(2) the mockup trainer is an equally effective device for teaching these ground procedures;
(3) groung cockpit procedures can be taught quite effectively in devices of low physical fidelity which are quite inexpensive to fabricate;
(4) ground cockpit procedures can also be learned rapidly in the aircraft without benefit of a

f. Experimental Setting/Training Context: Voluntary experiment

g. Statistical Methods: Not specified

h. Variables Being Manipulated:
  (1) Training Devices:
    (a) sophisticated computerized cockpit procedures trainer 2-C-9;
    (b) rudimentary mockup of aircraft cockpit made of plywood and photographs
  (2) Fidelity Levels: High and Low
  (3) Type of Task/Skill Required: Ground cockpit procedures: 174 items
  (4) Task Difficulty: Medium

i. Stage of Training: Experimental

j. Trainee Sophistication: High; all had minimum 291 hours, maximum 4,962 hours flight experience

k. Incorporation of Device into P.O.I.:

l. User Acceptance or Attitude:
  (1) Instructors: Not discussed
  (2) Students: Not discussed

m. Use of Instructional Features:
  (1) Intensity: Not discussed
  (2) Features used: Not discussed

9. Abstract:

a. Study Synopsis: It has been shown that transfer of training from a simulator to actual equipment does not necessarily vary in proportion to the "face validity" or physical fidelity of the simulator. The evidence indicates that task fidelity is more important than physical fidelity in the transfer of training. This study compared the effectiveness of a low-fidelity, low- cost simulator with that of an expensive, high-fidelity device in teaching ground cockpit procedures. Two groups of 10 volunteers each, all of whom had considerable flight experience on other aircraft, were given equal amounts of training time on the respective simulation devices. The performance of these groups was compared with the "base line" performance of an additional 10 volunteers who were given training in the actual aircraft.

No significant differences were found in the accuracy or speed of test performance by either of the

1. Authors: Prophet, Wallace W., & Boyd, H. Alton

2. Title: Device-Task Fidelity and Transfer of Training: Aircraft Cockpit Procedures Training

3. Source: HumRRO Technical Report 70-10, July 1970

4. Topic Keywords: Simulated Flight Training ; Transfer of Training ; Low Fidelity .

5. Short Summary: No significant differences in training effectiveness were found between cockpit procedures training devices of high and low physical fidelity, as measured by subsequent trials in actual aircraft. This suggests that task fidelity is more important than physical fidelity in the transfer of procedural training.

6. Devices:

   a. Sophisticated computerized cockpit trainer

   b. Inexpensive mock-up of aircraft cockpit

7. Institutions:

   a. Sponsor: Office, Chief of Research and Development, Department of the Army

   b. Performing Organization: HumRRO Div. No. 6 (Aviation), Fort Rucker, AL 36362

8. Type of Article: Experiment

   a. Number of Groups: Two Group Post Test

   b. Description of Groups:
      (1) Subjects: 20 non-student volunteers, rated Army aviators
      (2) Controls: 10 same

   c. Tests or Trials/Timing: post-test flight in actual aircraft

   d. Number of Different Types of Measures: 1

   e. Description of Measurements and Ratings:
      (1) Performance Measures: Instructor-scored checklist trials in actual aircraft, scored by
         (a) fraction of errors;
         (b) time to accomplish
      (2) Supervisor Ratings: None applicable

transfer task; only in Experiment I, however, where experienced pilots were the subjects, did the T&E group also perform better (but only marginally) during the training trials; in Experiments II and III, learning curves showed little difference between groups.

In all experiments, stress (electric shocks) significantly degraded performance for all groups, but there was no significant difference between groups except in Experiment I (again, the experienced pilots), where the T&E group's performance suffered less than the prompted group's.

c. Authors' Conclusions: From the first three experiments, it appears that during training, each method chosen is equally efficient; but after training, trial-and-error methods assert their superiority in the transfer task. The overall evidence from these experiments indicates that trial-and-error is a superior method of training when compared with highly prompted procedures if the task is one of difficult perceptual learning such as the one involved here. The indiscriminate use of prompting techniques for teaching complex tasks is open to question.

From the fourth experiment, it appears that it is possible to train in resistance to stress by placing the trainee under a low to moderate amount of stress during the training program. The stress trained student should then perform better when under a higher stress condition than a student who has not been placed under the stressful training condition.

(1) Training conditions with training target
    (a) Trial-and-error with feedback
    (b) Prompted (errorless) without feedback
    (c) Initially prompted without feedback, but after 3 trials, trained via trial-and-error with feedback
(2) Testing conditions with either training or "transfer" target (a different picture)
    (a) No feedback
    (b) Stress condition: small electric shock administered if in error (no other feedback)

Somewhat different was Experiment IV on the same task, which tested the hypothesis that subjects who were trained under moderate stress might perform better in a stressful transfer task than those who were trained with little stress. In this experiment, during training one group received positive feedback on correct execution-- the word "good" from the experimenter--while the other group received negative feedback, when in error, in the form of a small electric shock. The stress test condition, which was represented by a single trial at the end of the testing, threatened subjects with a substantial (200 volt) electric shock for error.

b. Results:

(1) Key Data:

(a) From experiments I, II, and III; Transfer trials only:
Experiment I: trial-and-error group mean error 664 ft.; prompted group mean error 1,115 ft., significant at .05 level
Experiment II: T&E group mean error 921 ft.; prompted group 1,211 ft. ($p < .05$)
Experiment III: T&E group mean error 846 ft.; combined prompted-and T&E group 1,000 ft. ($t = 1.59$, p [illegible] .1)

(b) From experiment IV: No significant difference on transfer trials between groups, except on the single stress transfer trial, the positively reinforced group's mean error was 532 ft. and the negatively reinforced group's was 414 ft. ($t = 2.21$, p [illegible] .05)

(2) Verbal Description: Experiments II and III confirmed findings of Experiment I, that, in agreement with most of the literature, T&E groups performed better than prompted groups on a

e. Description of Measurements and Ratings:
   (1) Objectively measured deviation from correct estimation of range
   (2) Heart-rate of subjects (to verify stress)

f. Experimental Setting/Training Context: laboratory, hands-on

g. Statistical Methods:

h. Variables Being Manipulated:
   (1) Training Devices, as above section 6. BY METHOD:
      (a) With or without cue light (for "error-free" prompted learning)
      (b) With or without electric shock (for supplying stress in Experiments I-III; and for supplying negative learning reinforcement, Experiment IV)
   (2) Fidelity Levels:
      (a) Physical: Low
      (b) Functional: Low
   (3) Type of Task/Skill Required: Simulated firing; psychomotor, perceptual, part-task
   (4) Task Difficulty: Medium

i. Stage of Training: skill

j. Trainee Sophistication: Experiment I, intermediate; Experiment II, novice

k. Incorporation of Device into P.O.I.: lock-step (experimental)

l. User Acceptance or Attitude: not discussed

m. Use of Instructional Features:
   (1) Intensity: intensive
   (2) Features used: augmented feedback

9. Abstract:

a. Study Synopsis: This paper discusses four experiments evaluating different training techniques in teaching a moderately complex perceptual-psychomotor task. The task under study was range-estimation as measured by the accuracy of initiation of fire on a stationary target in a simulated strafing run. In experiments I through III, several trial-and-error versus highly prompted (highly- cued, errorless) training and testing conditions were applied, as follows:

1. Authors: Prather, Dirk C., Berry, Gene A., & Jones, Gerald L.

2. Title: Four In-Depth Studies of a Flight Training Skill: Trial and Error versus Prompted Learning Evaluated on Efficiency, Transfer, and Stress

3. Source: U.S. Air Force Research Report 71-11, December 1971

4. Topic Keywords: Range estimation task ; Trial-and-error training ; Errorless training ; Prompted learning ; Stress .

5. Short Summary: Comparison of trial-and-error versus prompted learning techniques in training for a complex perceptual-psychomotor skill finds the trial-and-error technique superior when transferred to a similar task.

6. Devices: Scaled two-dimensional projection of strafing run area target, and trigger for simulated firing. Projected picture differed between training and transfer.

7. Institutions:

   a. Sponsor: Dean of Faculty, U.S. Air Force Academy, CO 80840

   b. Performing Organization: same

8. Type of Article: Experiment (4 experiments)

   a. Number of Groups: Experiment I, 6; Experiment II, 4; Experiment III, 2; Experiment IV, 2

   b. Description of Groups:

   EXPERIMENT I: (1)-(6) 16 each group, moderately experienced male student pilots, randomly assigned

   EXPERIMENT II: (1)-(4) 15 each group, inexperienced male student pilots, randomly assigned

   EXPERIMENT III: (1)-(2) 20 each group, same as Exp. II

   EXPERIMENT IV: (1)-(2) 20 each group, same as Exp. II

   c. Tests or Trials/Timing: in-process trials; post-tests

   d. Number of Different Types of Measures: 2

error method. The mean of the trial-and-error group was 16% better on performance than the mean of the errorless group, although the difference could not be considered (more than marginally) significant due to the large amount of variance in performance because of the low number of training trials.

The results on efficiency of training may be contrary to the literature because of the difficulty of the training. Possible there is a point in the difficulty of discrimnination tasks at which trial-and- error methods overtake and pass errorless procedures in efficiency. Another reason for the results may be that most adults have a long history of trial-and-error learning; they probably have learned to be efficient at this process....

In agreement with most of the literature, however, trial-and-error training was superior to errorless training when teaching for transfer. These results extend the literature to a more difficult perceptual task.

Answers were supplied by depressing a trigger. The projected target in training trials was a conventional cloth training target. During training, trial-and-error subjects were given feedback on the accuracy of their responses--by the experimenter's verbal statement of actual distance at which they had fired, immediately after every firing. Error-free subjects were required to fire at the appearance of a cue light which came on at the correct approach distance.

After the first set of training trials, both groups were given trials without feedback and without cuing lights for either. After training and trials with the cloth target, the six groups were tested with the same device in either of three ways:

(1) "Transfer": the projected target was changed to a MIG-21;
(2) "Stress": the target was the cloth practice target but subjects received electric shocks for incorrect responses
(3) "Transfer-with-Stress": target was MIG-21 and shock was administered for incorrect responses.

b. Results:

(1) Key Data:

MEAN ERROR IN FEET BY TRAINING CONDITION

Training Condition	Transfer Test	Stress Test	Transfer plus Stress Test
Trial-and-error	664	427	1,080
Errorless	1,115	750	1,218
	$p < 0.05$	$p < 0.01$	not significant

(2) Verbal Description: The trial-and-error group showed a marginally significant superior performance on the learning trials when neither group was given feedback or cues.

The trial-and-error group performed with significant and larger superiority on the transfer test and on the stress test. There was no significant difference on the transfer-with-stress tests.

c. Author's Conclusions: Contrary to most of the literature, the errorless method did not teach the experimental task more efficiently than the trial-and-

e. Description of Measurements and Ratings: Objectively measured deviation from correct estimate of target range.

f. Experimental Setting/Training Context: Laboratory experiment, hands-on

g. Statistical Methods: One-way ANOVA

h. Variables Being Manipulated:
   (1) Training Devices: Two-dimensional projection of strafing run area and target
      (a) With or without cue light (for error-free cuing of response;
      (b) with or without electric shock to wrist (for stress)
      (c) projected either picture of cloth target for trials; or picture of MIG-21, for transfer
   (2) Fidelity Levels:
      (a) Physical: Low
      (b) Functional: Medium
   (3) Type of Task/Skill Required: motor; perceptual; part-task (very narrowly-defined task)
   (4) Task Difficulty: Medium

i. Stage of Training: skill

j. Trainee Sophistication: intermediate and expert

k. Incorporation of Device into P.O.I.: not applicable

l. User Acceptance or Attitude:
   (1) Instructors: not specified
   (2) Students: not specified

m. Use of Instructional Features:
   (1) Intensity: intensive
   (2) Features used: not specified

9. Abstract:

a. Study Synopsis: This experiment attempted to evaluate an error-free training method wherein error-commission was practically impossible and no feedback on performance was given to the error-free-trained subjects. The task involved a visual estimate of correct distance from a target to be fired on at the optimum point in a strafing run approach, as represented by a movie film projection.

1. Author: Prather, Dirk C.

2. Title: Trial-and-Error Versus Errorless Learning: Training, Transfer, and Stress

3. Source: American Journal of Psychology, 1971, Vol. 84, No. 3

4. Topic Keywords: Range-estimation-task ; Trial-and-error learning ; Errorless learning ; Error-free learning ; Stress .

5. Short Summa.y: A comparison of training methods for teaching a transferable perceptual skill finds the trial-and-error method superior to an error-free method.

6. Device: Two-dimensional projection of strafing-run area and target; trigger for simulated firing; shock-administering device; and cue light

7. Institutions:

   a. Sponsor: not named; some agency of U.S. Air Force

   b. Performing Organization: not named; some agency of Arizona

8. Type of Article: Experiment

   a. Number of Groups: 6

   b. Description of Groups:
      (1) Subjects: trained by error-free method
         (a) 16 male students at Luke AFB, tested for Transfer
         (b) 16 same, tested for Stress
         (c) 16 same, tested for Transfer-with-Stress
      (2) Subjects: trained by trial-and-error method
         (a) 16 same, tested for Transfer
         (b) 16 same, tested for Stress
         (c) 16 same, tested for Transfer-with-Stress

      NOTE: All subjects randomly assigned from a pool of 96 men with age range 21-44, mean age 25.9 years. All moderately-experienced pilots who had received wings in a USAF flight training program.

   c. Tests or Trials/Timing: In-Process Trials; Immediate Post-Tests

   d. Number of Different Types of Measures: 1

total time than those trained exclusively in the aircraft. A Transfer Effectiveness Ratio was developed to show the relative transfer effectiveness of simulator training (see "Authors' Conclusions").

A correlation between instructors' predictions and subsequent student performance indicated that initial evaluations made in the simulators were better guides to eventual performance than evaluations made in the aircraft.

The third objective was answered by quantitative descriptions of performance criteria in maneuvers proposed by the 15 flight instructors. These descriptions showed possiblilities for developing objective, quantifiable performance criteria that could be specified through further flight experimentation.

b. Results:

(1) Key Data:

		Hours to Checkflight		
	Final Score	Aircraft	Ground Trainer	Total
Aircraft-trained Students (N=11)	4.07	47.60	0	47.60
AN-T-18-trained Students (N=13)	4.01	36.90	10.73	47.63
GAT-1-trained Students (N=12)	4.13	36.99	10.89	47.88

(2) Verbal Description: On final flight checks, students who received approximately 11 hours ground- based simulator training time in place of aircraft training time performed as well as those who received all their training in the aircraft. Moreover, there was a positive correlation between hours-to-checkflight time and instructor predictions of hours-to-checkflight time based on pre-experiment observation of students in the simulators, whereas there was not a positive correlation between hours- to-final checkflight time and instructor predictions based on observations of students in the aircraft.

c. Authors' Conclusions: A "Transfer Effectiveness Ratio" expressing the transfer effectiveness of

simulator training versus aircraft training can be determined by a simple computation:

$$TER = (Yc - Ye) / Xe$$

Where Yc = flight hours required by control group to reach some criterion of proficiency in the aircraft; Ye = corresponding value for experiemental group; Xe = ground trainer hours received by experimental group.

At some point the incremental transfer effectiveness ratio for an additional hours of ground trainer time will fall below the trainer/aircraft cost ratio. At this point it will become unprofitable to give further ground training in the same flight tasks.

Ground-based flight trainers, as represented by the new GAT-1 and the old Blue Box, can yield high transfer when used by flight instructors who are left to their own devices in a routine training program.

The prediction of pilot aptitude based on a student's performance during his first two hours in a ground-based trainer appears promising.

1. Author: Puig, Joseph A.

2. Title: The Training Effectiveness of Device 3A105, Tracked Vehicle Driving Trainer (M48A3)

3. Source: Technical Note: NAVTRAEQUIPCEN TN-36, November 1972

4. Topic Keywords: Transfer of Training ; Tank Driving Simulator ; Tracked Vehicle Driving Simulator .

5. Short Summary: A transfer-of-training study of a tracked vehicle driving simulator, Device 3A105, found it cost-efficient (at a cost of $2.10 per hour) in training basic tank driving tasks in comparison with the actual tank (at a cost of $6.05 per hour). There were no significant performance differences found between the two groups.

6. Devices:

a. M48A3 medium weight tank

b. Device 3A105 Tracked Vehicle Driving Simulator (instrument driving; analog computer driven)

7. Institutions:

a. Sponsor: Naval Training Equipment Center, Orlando, FL 32813

b. Performing Organization:
Tracked Vehicle School, Marine
Corps Base, Camp Pendleton, CA 92055

8. Type of Article: Experiment

a. Number of groups: 2

b. Description of groups:
(1) Subjects: 19 enlisted men and 3 officers, students at Marine Tracked Vehicle Driving School
(2) Controls: 12 enlisted men and 3 officers, same

c. Tests or trials/timing: post-tests

d. Number of different types of measures: 4

e. Description of measurements and ratings:
(1) Instructor ratings
(2) Time to proficiency, practice driving time,

instructor time
(3) Number of instructor corrections
(4) Written examination scores

f. Experimental setting/training context: institutional, hands-on

g. Statistical methods: ANOVA

h. Variables being manipulated:
(1) Training devices: as above, section 6
(2) Fidelity levels (of simulator):
(a) Physical: Medium
(b) Functional: Medium
(3) Type of task/skill required: tracked vehicle driving; operations, cognitive, psychomotor, perceptual, whole-task
(4) Task difficulty: Medium-high

i. Stage of training: introduction; skill

j. Trainee sophistication: not specified

k. Incorporation of device into P.O.I.: lock-step

l. User acceptance or attitude: not discussed

m. Use of instructional features:
(1) Intensity: not specified
(2) Features used: Malfunction selection, others not specified

9. Abstract:

a. Study Synopsis: A transfer-of-training study was designed to compare the effectiveness of equal amounts of training time in an actual tank and in a tracked vehicle driving simulator. The experimental group of 22 student drivers received training time in the simulator equal to the tank training time received by the control group of 15 student drivers. Both groups were tested by checkride in an actual tank on eight separate items, ranging from gear selection to moving into and out of deep ditches, and ground guiding by day and night.

An analysis of per-hour costs of tank training and simulator training was also done.

b. Results:

(1) Key Data:

Enlisted Class, January '71, Tank Driver
Training Ratings Scales, Items 2-9,
Unweighted Means

	Tank-trained	Simulator-trained
Total Score	26.6	27.8

(2) Verbal Description: The totals of the instructor scores on the eight items on the checkrides for the two groups is shown above. This difference was not statistically significant, nor were there significant differences on any of the individual items. Other performance measures, such as number of instructor corrections, also showed no significant differences.

The cost of training per hour in the trainer is $2.10; in the tank, $6.05.

c. Author's Conclusions: Since the training time required by the tank group and trainer group is approximately the same, it is concluded that there is a one-to-one substitution ratio between the trainer and the vehicle itself insofar as driver training is concerned. In addition, since there is a significant cost difference between the two methods of training, the trainer represents a more cost-effective method of training tank drivers. It is even more cost-effective when considering the savings in transmission repair costs by using the simulator. Novice drivers have been responsible for breakage of transmission gear trains while practicing in the actual vehicle.

1. Authors: Randle, Robert J. Jr., Tanner, Trieve A., Hamerman, Joy A., & Showalter, Thomas H.

2. Title: The Use of Total Simulator Training in Transitioning Air-Carrier Pilots: A Field Evaluation

3. Source: NASA Technical Memorandum 81250, January 1981

4. Topic Keywords: Transition Training ; Field Evaluation ; Flight Simulator ; Landing Maneuver .

5. Short Summary: A study of checkflight performances of experienced commerical pilots transitioning to B727 and DC10 aircraft showed no significant differences relative to whether they were trained completely on simulators or mostly in the aircraft.

6. Devices: High Fidelity Visual and Instrument Flight Simulators for B727 and DC10

7. Institutions:

   a. Sponsor: United Airlines

   b. Performing Organization: Ames Research Center, NASA

8. Type of Article: Experiment

   a. Number of Groups: 4

   b. Description of Groups:
      (1) Subjects for B727 Training: 28 experienced commercial pilots
      (2) Controls for B727 Training: 20 same
      (3) Subjects for DC10 Training: 26 same
      (4) Controls for DC10 Training: 20 same

   c. Tests or Trials/Timing: one post-test (checkflight)

   d. Number of Different Types of Measures: 4

   e. Description of Measurements and Ratings:
      (1) Instrument Data:
         (a) Descent rate
         (b) Descent path deviation
         (c) Sink rate at touchdown
         (d) Vertical acceleration at touchdown
         (e) Lateral acceleration at touchdown
         (f) Standard deviation of vertical acceleration at touchdown plus 2 sec.

(g) Standard deviation of lateral acceleration at touchdown plus 2 sec.
(2) NASA-observer objective and rating-scale
(3) Checkpilot rating scale
(4) Trainee ratings of training

f. Experimental Setting/Training Context: NASA Field Study (as described by experimenters) at United Airlines Flight Training Center

g. Statistical Methods: Multivariate analysis: discriminant analysis; principal-components analysis

h. Variables Being Manipulated:
(1) Training Devices: High fidelity visual and instrument flight simulators for B727 and DC10
(2) Fidelity Levels:
(a) Physical: high
(b) Functional: high
(3) Type of Task/Skill Required: landing maneuvers
(4) Task Difficulty: high
(5) Skills required by task: motor, perceptual, cognitive

i. Stage of Training: transition

j. Trainee Sophistication: expert

k. Incorporation of Device into P.O.I.: unspecified

l. User Acceptance or Attitude:
(1) Instructors: not discussed
(2) Students: mixed but generally good

m. Use of Instructional Features: intensive

9. Abstract:

a. Study Synopsis: The purpose of this study was to evaluate a transition training program that totally replaced the airplane with a state-of-the-art flight simulator. The evaluation procedure involved analysis of various objective measures and subjective ratings of pilot performance as a step toward objectifying and standardizing assessment techniques.

135 experienced pilots transitioning to B727's and DC10's at the United Airlines Flight Training Center were divided into two pairs of groups, of which all completed initial normal ground school and normal initial simulator training. Thereafter the control

groups (one each for each aircraft) progressed to training in the aircraft (as normal); the experimental groups (one for each aircraft) received all their training, prior to checkflight, in the simulators.

Evaluation of 19 different performance measures from five sets of data (NASA observer ratings, checkpilot ratings, trainee ratings, instrument-measured inflight data, instrument-measured simulator data) showed no statistically significant differences between the groups on their performance on a checkflight which duplicated standard FAA checkflight procedures. The small (though statistically not significant) superiority of the aircraft-trained pilots could easily be attributed to the experimental state of the simulator training program, and point to the need for work on the simulator training curriculum.

Comments by trainees identified specific deficiencies in simulator realism, particularly in tjhe perception of depth, and of sink rate. However, there was a high and statistically reliable correlation between sink rates in the simulator and in the aircraft, which indicates that individual performance differences could be discerned in the simulator. This implies a possible capability for predicting aircraft performance from simulator data using a multiple regression equation. Furthermore, precise and detailed data from this study comparing performance in the simulator with performance by the same pilots in the aircraft may provide insight into the differences and similarities between simulator and aircraft in respect to sink rate and other phenomena.

b. Results:

(1) Key Data:

Phase I Study Results by Aircraft Type

		B-727		DC-10	
		No.	%	No.	%
Sim	Pass	19	68	18	69
	Fail	9	32	8	31
A/C	Pass	18	90	20	100
	Fail	2	10	0	0

Note: The aircraft-trained groups served as control groups.

(2) Verbal Description: On all measures a significant overlap in performance between simulator-trained and aircraft-trained pilots was

obvious.... On the basis of these performance measures it was not possible to determine statistically which type of training the pilots had experienced. On most measures there was a small difference in favor of the aircraft-trained group. But the differences were not statistically significant. Both training groups improved over the three landings of the check ride.

High sink rates in the simulator were associated with high sink rates in the aircraft (and low with low). The correlation was high and statistically reliable.

c. Authors' Conclusions: The two training groups were seen to be statistically indistinguishable on the basis of the many performance indices that were utilized. Given the very high experience level of the transitioning pilots, there is probably such a swift transfer of previously learned skills that any real differences have evaporated before they can be measures by the techniques used in this study.

The slight (though statistically nonsignificant) edge held by those who had received aircraft training motivates one to find ways in the simulator curriculum to eliminate or decrease that small difference. It seems reasonable to shift emphasis to the question of how to maximize simulator training; it would seem uneconomical to use the aircraft in a separate training module just to erase the small differences shown in this study.

The problems of simulator realism persist (as judged by trainee comments). Why are sink rates higher in the simulator? It is known that these are recurrent findings in simulator research, but it is not known why. This study, comparing the same pilots' performances in simulator and aircraft with very precise indices, may provide insight into transfer phenomena. A possible capacity for predicting aircraft performance from simulator data using a multiple regression equation was indicated.

1. Authors: Reicher, Gerald M., Davidson, Brian J., Hawkins, Harold L., & Osgood, Gilbert

2. Title: Low Cost Simulation of Piloting Tasks

3. Source: Center for Cognitive and Perceptual Research, University of Oregon, Technical Report, January 1980

4. Topic Keywords: Flight Simulation ; Instrument Flight Simulation ; Low Fidelity .

5. Short Summary: An attempt to validate a low-cost computer-drive flight simulator of low physical fidelity produced some correlations of performance on the device with the subjects' training background. Results suggest the usefulness of the simulator in measuring flight proficiency.

6. Device: Computer driven instrument flight simulator with 3 instruments resembling real-aircraft instruments.

7. Institutions:

a. Sponsor: Personnel and Training Research Programs, Psychological Sciences Division, Office of Naval Research

b. Performing Organization: Center for Cognitive and Perceptual Research, University of Oregon, Eugene, OR 97403

8. Type of Article: Experiment

a. Number of Groups: 1

b. Description of Groups: (number not specified, 11 observations taken in the smallest-sample trial) trainees of varying flight experience from Lane Community College Flight Technology Program

c. Tests or Trials/Timing: Two in-process trials

d. Number of Different Types of Measures: 1

e. Description of Measurements and Ratings: Deviation from prescribed flight track, instrument-recorded and sub- sequently judged by two judges independently

f. Experimental Setting/Training Context: Laboratory; hands-on

g. Statistical Methods: t-test; correlation

h. Variables being manipulated:
(1) Training Device: Computer-driven instrument flight simulator with 3 instruments resembling real- aircraft instruments. The training device was also the testing device.
(2) Fidelity Levels:
(a) Physical: Low
(b) Functional: Medium-high (the experiment was actually an attempt to assess this variable)
(3) Type of task/skill required: cognitive, psychomotor, perceptual, part-task

i. Stage of Training: familiarization, skill

j. Trainee Sophistication: novice and intermediate

k. Incorporation of Device into P.O.I.: not applicable

l. User Acceptance or Attitude: not discussed

m. Use of Instructional Features:
(1) Intensity: incomplete
(2) Features used: Number/Quality of Responses; others not specified

9. Abstract:

a. Study Synopsis: An attempt was made to validate the functional fidelity of an instrument flight simulator which had low physical fidelity, by correlating performance on the simulator with subjects' flight background. A computer program was written especially for the experiment, which subjected pilots to simulated wind and turbulence. The experimental task was to follow a prescribed flight course in three progressively more difficult wind and turbulence conditions. Instruments provided were: (1) similar to a directional gyro, (2) similar to a turn indicator; and (3) similar to a course deviation indicator and TO/FROM indicator of a VOR receiver. Besides performing the flight task at three levels of difficulty during initial trials, the pilots were additionally required to perform the flight task while also performing auditory interference, visual interference, and cognitive (cal[illegible]ation) interference tasks.

The device recorded the flight course which was then rated in comparison with the prescribed flight course by two judges independently, based "primarily on

accuracy and smoothness."

The pilots' performance on the experiment task was then correlated with their flight training backgrounds.

b. Results:

(1) Key Data: Correlation between training hours and simulator performance with the simultaneous calculation task was -.54 for the easier task and -.68 for the difficulty task. Since one is the highest rank, the negative correlations with hours of training are as expected.

(2) Verbal Description: A few words of caution are in order about interpretation of these high correlations. Much data were lost due to computer failures and subject attrition so that the numbers of observations are small. Although both of the scores are significant (a t-test with $p \leq .05$ was used throughout) the actual values of the correlations should not be taken as good estimates of accounted for variance.

c. Authors' Conclusions: Tentative validation of the simulation was obtained. The simulator seems to be sensitive to some of the important aspects of pilot training.

It seems likely that discovering good pilot ability is best done with techniques using information overload. Many pilot tasks are not demanding in most situations. On instruments, in turbulence with one or two radios out, and going twice normal speed might make this task more challenging and discriminating of those who can handle bad situations while piloting. This is the sort of challenge that can be set up by a simulation.

The flexible simulator also allows more discriminating, repeatable, accurate measurement.

1. Authors: Reid, Gary B., & Cyrus, Michael

2. Title: Transfer of Training with Formation Flight Trainer

3. Source: AFHRL-TR-74-102, December 1974

4. Topic Keywords: Flight Training ; Transfer of Training ; Formation Flight Training ; Simulation .

5. Short Summary: Five sorties on a high-fidelity flight simulator were found as effective as two actual- aircraft sorties in training for formation flight in a jet training aircraft.

6. Devices: Prototype high fidelity Formation Flight Trainer, proving realistic 2-aircraft formation simulation via television projection

7. Institutions:

a. Sponsor: HQ Air Force Human Resources Laboratory (AFSC), Brooks AFB, TX 78235

b. Performing Organization: Flying Training Division, AFHRL, Williams AFB, AZ 85224

8. Type of Article: Experiment

a. Number of Groups: 6 (3 for each sub-study)

b. Description of Groups:

Study One -
(1) Subjects: Undergraduate Pilot Trainees with approximately 112 hours jet aircraft flight training
(a) approximately 24 trained on Formation Flight Simulator
(b) approximately 24 minimally trained; familiarization with test aircraft only
(2) Controls: approximately 24 same; trained by normal syllabus, on aircraft

Study Two -
(1) Subjects: Undergraduate Pilot Trainees with approximately 90 hours total jet aircraft flight training, including 8 hours formation flight
(a) 16 trained on Formation Flight Simulator
(b) 16 minimally trained; familiarization with test aircraft only
(2) Controls: 16 same; trained by normal

syllabus, on aircraft

c. Tests or trials/timing: One post-test checkflight

d. Number of Different Types of Measures: 1

e. Description of Measurements and Ratings: 12-point performance scale, scored by Instructor Pilot on checkflight

f. Experimental Setting/Training Context: Institutional-- hands-on

g. Statistical Methods: ANOVA; "a posteriori test" (Tukey's HSD)

h. Variables Being Manipulated:
(1) Training Devices: Prototype high fidelity Formation Flight Trainer, providing realistic 2-aircraft formation simulation via television projection
(2) Fidelity Levels:
(a) Physical: unspecified, presumably medium-high to high
(b) Functional: high
(3) Type of task/skill required: aircraft formation flight; operations, cognitive, psychomotor, motor, perceptual, procedural
(4) Task Difficulty: High

i. Stage of Training: familiarization; skill; transition

j. Trainee Sophistication: intermediate

k. Incorporation of Device into P.O.I.: lock-step and instructor-managed

l. User Acceptance or Attitude:
(1) Instructors: not discussed
(2) Students: not discussed

m. Use of Instructional Features:
(1) Intensity: intensive
(2) Features used: not specified

9. Abstract:

a. Study Synopsis: This study, in two roughly identical parts, sought to evaluate the training effectiveness of a prototype high fidelity formation flight trainer simulator (FFT) by a transfer of

training design.

Subjects were trainees in the USAF Undergraduate Pilot Training Program in transition from basic contact to formation flight. Both parts of the study--"Study One" and "Study Two"--were conducted identically except that the testing procedures in "Study Two" were more controlled and more reliable. Controls were students trained via the standard syllabus which included three formation-flight trials in aircraft prior to checkflight (2 training trials and checkflight orientation run). There were 2 groups of experimental subjects: (1) those who received neither aircraft nor simulator training but were given an orientation flight in the aircraft prior to checkflight; (2) those who received no aircraft training but 5 simulated formation sorties in the FFT instead, and an orientation flight in the aircraft prior to checkflight. Total number of personnel in the study: 118

Transfer of training was measured by a 12-point continuous-scale grade on the checkflight, scored by the Instructor Pilot.

b. Results:

(1) Key Data:

Differences Among Means of Performance Scores -- Study Two (N=42)

Groups	Scores
FFT Trained	55.31
Minimally Trained	43.49
Syllabus Trained	53.41

ANOVA, Performance Scores (Study Two)

Source	DF	MS	F	
Between Groups	2	449.51	5.33	($p < .05$)
Within Groups	39	84.23		
Total	41			

(2) Verbal Description: Students trained in the FFT scored significantly better than the essentially untrained students, indicating that simulator training resulted in improved performance in the aircraft (not just due to the pre-checkflight orientation flight). However, differences between FFT-trained groups and the syllabus-trained groups fail to attain statistical significance.

c. Authors' Conclusions: Results from these studies,

especially in light of their repeatability, provide conclusive evidence that the formation simulator is an effective training device. Comparisons of checkflight scores lead to the conclusions that both training methods, simulator and real-aircraft formation flights, are effective at this early stage of the students' skill acquisition.

It is suggested that the development of effective instructional strategies, the definition of the amount of useful simulator practice, and determination of how the formation simulator can best complement aircraft instruction, will result in a substantial increase in the FFT's training effectiveness.

1. Authors: Riedel, James A., Abrams, Macy L., & Post, David

2. Title: A Comparison of Adaptive and Nonadaptive Training Strategies in the Acquisition of a Physically Complex Psychomotor Skill

3. Source: Navy Personnel Research and Development Center Training Report 76-24, December 1975

4. Topic Keywords: Welder Training ; Arc Welding Simulation ; Reinforcement Principles ; Adaptive Training ; Training Effectiveness .

5. Short Summary: A comparison of adaptive and nonadaptive training strategies in teaching a complex psychomotor skill (arc welding) finds no significant difference in skill acquisition between the two training conditions.

6. Device: Manual arc welding simulator (adaption controlled by experimenter, not automatically)

7. Institutions:

   a. Sponsor: Navy Personnel Research and Development Center, San Diego, CA 92152

   b. Performing Organization: same

8. Type of Article: Experiment

   a. Number of Groups: 2 (with 6 subgroups under each condition)

   b. Description of Groups:
      (1) Subjects: 30 Hull Maintenance Technician Fireman and Firemen Apprentice Trainees (6 subgroups, for 6 levels of training difficulty)
      (2) Subjects: 30 same, subgroups same

   c. Tests or Trials/Timing: Pre- and Post-Test

   d. Number of Different Types of Measures: 1

   e. Description of Measurements and Ratings: Error rates in each of 3 spatial dimensions

   f. Experimental Setting/Training Context: Laboratory, hands-on

   g. Statistical Methods: Analysis of Covariance

h. Variables Being Manipulated:
(1) Training Devices: same for both groups. Technique was the variable of interest.
(a) Adaptive technique (machine tolerances tightened by experimenter when trainee showed improvement)
(b) Fixed technique (machine tolerances not varied)
(2) Fidelity Levels:
(a) Physical: Medium
(b) Functional: Low
(3) Type of Task/Skill Required: Arc welding; psychomotor, part-task
(4) Task Difficulty: High (with 6 levels; perhaps Medium-High to High)

i. Stage of Training: introduction; skill

j. Trainee Sophistication: novice

k. Incorporation of Device into P.O.I.: not applicable (experimental)

l. User Acceptance or Attitude: not discussed

m. Use of Instructional Features:
(1) Intensity: incomplete
(2) Features used: augmented feedback

9. Abstract:

a. Study Synopsis: This study compared the effects of using an adaptive technique versus a fixed technique in teaching a complex 3-dimensional perceptual and psychomotor skill (arc welding) on a simulator of low to medium fidelity. A secondary purpose was to measure the correlation between pre-training and post-training performance on the apparatus.

Subjects were 60 Hull Maintenance Technician Fireman and Fireman Apprentice trainees. Pre-tests and post-tests on the training apparatus were given to all subjects at four different levels of difficulty. Within each of the two main groups were six sub-groups trained at six different levels of task difficulty. All subjects trained by attempting to minimize error in three spatial dimensions simultaneously (in-out, side-to-side, and up- down) while moving a stylus over a prescribed simulated welding track. The fixed technique subjects worked within fixed margins of error throughout all 100 training trials; adaptively trained subjects were compelled to work within progressively

narrower margins as their performance improved.

Measures taken in the pre-tests and post-tests were of error in the three spatial dimensions.

b. Results: Results of analysis for three modes (stylus tip-to-target distance, tracking, and these two variables combined) yield no significant differences among various levels of practice difficulty. The correlation between variate and covariate (pretrials) for stylus tip-to-target surface distance was .71; for tracking, .69; for the combined variables, .74.

The effects of training schedules (adaptive and nonadaptive) were not found to be significantly different, either. All reliable measured dimensions showed no significant differences in test performance between the various levels of practice difficulty. Similarly, the effects of the training schedules, adaptive and nonadaptive, were not found to be significantly different. While neither of the main effects were significant, the average percent of improvement between pre- and post-tests for all subjects was 65.58% out of a possible 100%. Results also suggest no significant linear trend for adaptive and nonadaptive conditions across levels of practice difficulty.

c. Authors' Conclusions: Two primary hypotheses can be advanced to explain why the adaptive training condition did not prove superior to the nonadaptive: (1) the subjects in the adaptive mode were not able to detect progress because their error signal rates were held constant, and thus were subjected to negative motivational effects, and (2) adaptive techniques are not applicable in the present case due to the complexity of the task. The second hypothesis seems more plausible in explaining the present results. Abrams et. al. (1974) found that physically complex psychomotor skills are different than simple psychomotor skills and training strategies or techniques should consider the task complexity. Even tasks which appear to be simple can be quite complex because the psychological processes involved can range to higher forms of information processing. In the present study, the task may have involved processes that do not occur in many less physically complex tasks.

In the present case, a training technique that has been successfully employed with other psychomotor skills did not generalize to a more physically complex task, thus

indicating a limitation of that strategy. Further research is recommended on the interaction between physical task complexity and utility of adaptive training strategy.

For teaching the subject task, a fixed schedule, being cheaper, is recommended as the most cost-efficient method.

Simulator pretraining performance measures were highly correlated with simulator final performance. (R = .74). Since final simulator performance has previously been found to correlate with welding performance (R = .79), this suggests a potential use of the apparatus as a predictive instrument for arc welding.

1. Authors: Rigney, J. W., Towne, D. M., Moran, P. J., & Mishler, R. A.

2. Title: Field Evaluation of the Generalized Maintenance Trainer-Simulator: II. AN/SPA-66 Radar Repeater

3. Source: Behavioral Technology Laboratories Technical Report No. 90, Department of Psychology, University of Southern CA, November 1978

4. Topic Keywords: Maintenance Training Simulation ; Electronics Troubleshooting .

5. Short Summary: The versatility of a Generalized Maintenance Training Simulator to provide instruction on different types of electronics equipment is validated in a transfer-of-training study in the field.

6. Devices:

a. Simulator:
Generalized Maintenance Training Simulator , a computer-based simulator that automatically selects malfunctions and displays high-resolution color images of the equipment. Student interacts by touching with a small stylus.

b. Actual Equipment: AN/SPA Radar Repeater

7. Institutions:

a. Sponsor: Naval Personnel Research and Development Center, and Personnel and Training Research Programs, Psychological Sciences Division, Office of Naval Research, and Advanced Research Projects Agency

b. Performing Organization: Behavioral Technology Laboratories, Department of Psychology, University of Southern California

8. Type of Article: Experiment

a. Number of Groups: 1

b. Description of Groups: Subjects: 10 Navy electronics technicians

c. Tests or Trials/Timing: In-process trials of 33 problems; post-test of 4 problems

d. Number of Different Types of Measures: 1

e. Description of Measurements and Ratings: Time to complete problems

f. Experimental Setting/Training Context: laboratory, hands-on

g. Statistical Methods: not specified

h. Variables Being Manipulated:
(1) Training Devices: Generalized Maintenance Training Simulator
(2) Fidelity Levels:
(a) Physical: medium-low (2-dimensional microfiche projections of equipment)
(b) Functional: Medium-high
(3) Type of Task/Skill Required: Maintenance troubleshooting; cognitive; perceptual
(4) Task Difficulty: Medium-high

i. Stage of Training: familiarization, skill

j. Trainee Sophistication: intermediate

k. Incorporation of Device into P.O.I.: lock-step

l. User Acceptance or Attitude:
(1) Instructors: not specified (experimental personnel)
(2) Students: very favorable as indicated by questionnaire

m. Use of Instructional Features:
(1) Intensity: not specified, presumed intensive
(2) Features used: Restart/Resequence Capability; Malfunction Selection; Sign-in Capability; Number/Quality of Responses; Next Activity Feature; Automated Demonstration

9. Abstract:

a. Study Synopsis: This study was intended primarily to test the validity of two premises fundamental to the development of a Generalized Maintenance Training Simulator (GMTS), namely:
(1) that the system is general, and can therefore deliver training and simulation on any target system properly documented;
(2) that the data base can be prepared by technial personnel who are experts only in the behavior of the target system and the format of the required data base, but are not concerned with the nature of th GMTS program.

This study was not, therefore, designed to evaluate the training effectiveness of the device, and only loose control was exercised in the selection of subjects and problems.

The device itself is an interactive computerized system consisting of hardware and software as follows: (1) CRT which displays dynamic information about a simulated problem; (2) microfiche viewer, which displays color images of the target system; (3) touch input device (stylus) which provides student entry capability via touching the desired loction on the projected images of simulated equipment, or touching the commands on the command menu; (4) 10K minicomputer; (5) AED floppy disk drive mass data storage; (6) Cybernex (custom design) interface; and (7) UCSD PASCAL language.

The instructional format of the system remains invariable, whereas the content varies according to the equipment being simulated. Previously, the GMTS had been used experimentally to simulate a large, multi-equipment maintenance system for radio communication. The present study involved the AN/SPA-66 radar repeater, an indicator group which operates in conjunction with other radar equipment to provide a central display of radar returns. AN/SPA-66 equipment data was prepared entirely by two technical experts who were concerned only with supplying the specified data on the required format, who were not concerned with the nature of the GMTS program.

Ten Navy electronics technicians were trained in troubleshooting on the device, and subsequently tested on actual equipment. Their times to solution on both training trails and transfer test problems were recorded.

Student attitude was measured by questionnaire.

b. Results:

(1) Key Data:

Problem	Time-to-solution (in minutes)	SD (in minutes)
Practice 1	2.0	1.8
Practice 2	1.3	1.1
1	1.2	1.3
2	0.8	0.6
3	0.77	0.4
4	0.6	0.3
5	0.7	0.25

Note: Figures are reviewers' extrapolations from a graph.

(2) Verbal Description: None of the students encountered discernible difficulties in transitioning from GMTS to the test on the actual equipment. The figures above show the mean times and standard deviations for time-to-completion of practice problems and related test problems.

The student attitude questionnaire obtained generally very favorable responses only .04 of responses were "neutral", and none were unfavorable. More than half of the 16 respondents rated the GMTS either "Very Favorable" or "Favorable."

c. Authors' Conclusions: Since the sample size is extremely small, and problem difficulty was not a controllable variable, these results are only general indicators of training effectiveness.

The study demonstrated that equipment experts can effectively produce the data base required by GMTS to drive a comprehensive training simulation, and the generality of the training system was validated by use of a target system dissimilar to that previously simulated in an earlier experiment.

It appears from the limited data that troubleshooting skills derived from GMTS training can be transferred to the actual equipment.

1. Authors: Roscoe, Stanley N., & Williges, Robert C.

2. Title: Motion Relationships in Aircraft Attitude and Guidance Displays: A Flight Experiment

3. Source: Human Factors , 1975, 17(4), 374-387

4. Topic Keywords: Flight Simulation ; Aircraft Attitude ; Vestibular Cues ; Flight-Director Displays ; Guidance Displays ; Motion Cues .

5. Short Summary: A experiment was conducted using various flight- director displays in a laboratory flight simulator, with sometimes conflicting visual and vestibular cues given to non-pilot subjects. Indications are that results from experiments conducted either in fixed-base simulators or in ones providing highly distorted motion cues cannot be trusted if spatial orientation is a central consideration.

6. Devices: Beechcraft C-454 Flying Laboratory

7. Institutions:

   a. Sponsor: Office of Naval Research

   b. Performing Organization: Aviation Research Laboratory of the University of Illinois at Urbana-Champaign

8. Type of Article: Experiment

   a. Number of Groups: 1

   b. Description of Groups: 16 non-pilot, non-pilot-candidate Naval ROTC students

   c. Tests/Trials/Checkflights and Timing thereof: In-process Trials

   d. Number of Different Types of Measures: 1

   e. Description of Measurements and Ratings: Tracking Error; recorded manually when automatic recording equipment was found deficient

   f. Experimental Setting/Training Context: Institutional Laboratory, hands-on

   g. Statistical Methods: not specified

   h. Variables Being Manipulated:
      (1) Training Devices: Beechcraft C-454 Flying

Laboratory
(2) Fidelity Levels:
(a) Physical: unspecified
(b) Functional: unspecified; presumably high
(3) Type of Task/Skill Required: aircraft piloting; cognitive; psychomotor
(4) Task Difficulty: Medium-high
(5) Skills required by task: psychomotor; perceptual; cognitive

i. Stage of Training: introduction (experimental); skill

j. Trainee Sophistication: novice (very)

k. Incorporation of Device into P.O.I.: not applicable; continuous test

l. User Acceptance or Attitude:
(1) Instructors: not applicable
(2) Students: not applicable

m. Use of Instructional Features: intensive (test, not instruction)

9. Abstract:

a. Study Synopsis: This study investigated the impact of several combinations of visual and vestibular cues on flight maneuver performance in a laboratory flight simulator.

The Beechcraft C-454 flying laboratory can provide several different flight-director display configurations in either a pursuit mode or compensatory mode. An experiment was conducted with 16 non-pilot (non-pilot-candidate) Naval ROTC students to investigate the effects of using these different configurations, often in the presence of conflicting kinesthetic and vestibular cues, and thereby to determine an order of merit for the different displays.

A series of complex flight tasks were given to subjects in two basic modes--compensatory and pursuit--and in four different flight director display configurations--the conventional moving horizon (inside-out), moving airplane (outside-in), a hybria frequency-separated presentation applying the aileron position signal to the aircraft symbol to provide an immediate indication of imminent bank angle changes, and kinalog (time-lagged frequency separtion). The

checkflight criterion scores

f. Experimental Setting/Training Context: School

g. Statistical Methods: Unspecified

h. Variables Being Manipulated:
(1) Training Devices: 2F87F High-fidelity Flight Simulator
(2) Fidelity Levels:

	With-motion	No-motion
Physical	high	high
Functional	high	intermediate-high

(3) Type of Task/Skill Required: aircraft flight; cognitive, psychomotor, procedural
(4) Task Difficulty: high

i. Stage of Training: familiarization; skill

j. Trainee Sophistication: intermediate

k. Incorporation of Device into P.O.I.: unspecified; probably lockstep

l. User Acceptance or Attitude:
(1) Instructors: Good for with-motion; not so good without motion
(2) Students: Same as instructors

m. Use of Instructional Features: Intensive

9. Abstract:

a. Study Synopsis: This study was prompted by instructor pilots' subjective observations of deficiencies in the Training Device--that it did not contribute to learning the final phase of landing; and that in the without- platform-motion mode, it failed to give adequate fidelity and may have caused motion sickness. The study was designed to:
(1) Determine whether students who did not receive landing training in the simulator would perform just as well in checkflight landings as those who did (which would confirm the irrelevance of the simulated landing training to the aircraft flight landing task);
(2) Determine whether lack of simulated cockpit motion would produce a decrement in training;
(3) Determine whether motion sickness would result from an absence or presence of simulated cockpit

1. Authors: Ryan, Leonard E., Scott, Paul G., & Browning, Robert F.

2. Title: The Effects of Simulator Landing Practice and the Contribution of Motion Simulation to P-3 Pilot Training

3. Source: DTIC TAEG Report No. 63, September 1978

4. Topic Keywords: Landing Training ; Motion Simulation ; Transfer of Training ; Flight Simulation ; Training Effectiveness .

5. Short Summary: A study evaluating the 2F87F Flight Simulator showed it effective in training the final touchdown portion of the landing task. There were also some indications that simulated cockpit motion did not contribute in any large practical way to learning most simulated flight maneuvers, and that little evidence of motion sickness resulted from simulator experience either with or without cockpit motion.

6. Devices: 2F87F High-Fidelity Flight Simulator

7. Institutions:

a. Sponsor: Training Analysis and Evaluation Group, Orlando, FL 32813

b. Performing Organization: Same

8. Type of Article: Experiment

a. Number of Groups:
(1) Study One (landing training): 4
(2) Study Two (motion vs. no-motion): 2

b. Description of Groups:
(1) Study One:
(a) Controls: three groups of first-tour Naval aviators, who had completed undergraduate training, numbering 27, 39, and 10 respectively
(b) Experimental subjects: 19 same
(2) Study Two:
(a) Controls: one group of 39, same as Study One
(b) Experimental Subjects: one group of 11 , same

c. Tests or Trials/Timing: Post-test checkflights

d. Number of Different Types of Measures: 1

e. Description of Measurements and Ratings: Post-test

is evidence from this study that, at least for experienced pilots, the absence of realistic motion acceleration induces a relatively lasting decrement in performance. It appears that kinetic cueing should be provided when training pilots to react to emergencies even if the nature of the emergency is initially unrelated to the dynamics of the vehicle, since no consistent reliable relationships between the cues and the emergency were reflected in pilot response. This supports the hypothesis that the kinetic cues serve primarily an "alerting" function.

Superiority of the kinetic training condition manifested itself in the deterioration of the performance of the statically trained pilots; there was no appreciable evidence of differences in learning for either of the main experimental groups during the "training" cycle.

b. Results:

(1) Key Data:

(Out of 30 Flights)
Proportions of Successful Criterion Touchdowns as a Function of Number of Training Trials

"KINETIC" GROUP			"STATIC" GROUP				
Training Trials	Successes	%	Training Trials	Successes	%	z	p
15	18	60	15	13	43	1.42	-
30	13	43	30	8	27	1.33	-
45	19	63	45	10	33	2.75	<.01
60	18	60	60	19	63	.25	-
75	18	60	75	9	30	2.50	<.05
Total	86	57	Total	59	39	2.14	<.05

(2) Verbal Description: In respect to approach performance, there were significant differences between the kinetically and statically trained groups on 5 of the 10 measures during the criterion flights. In every case, performance of the kinetically trained group was significantly better than that of the statically trained group. During training, as the number of training trials increased, performance deteriorated for the statically trained group, on all measures except mean stick displacement where no difference occurred.

In respect to the measures taken at touchdown, the table above shows the differences between the groups on the criterion flights, as a function of the number of training trials. The kinetically trained group outperformed the statically trained group significantly overall, and on two of the five levels of training.

The superiority of kinetic training did not seem generally to be significantly related to the kind of emergency regime simulated; however, two of the failure regimes did show a significant effect on two performance measures, and one of the regimes was correctly recognized by pilots significantly more often under kinetic conditions.

c. Authors' Conclusions: Kinetic cueing is a valuable adjunct to airborne vehicle simulation systems. There

9. Abstract:

a. Study Synopsis: This study sought to evaluate the contribution of motion cues in training experienced pilots to land, in simulation, a high-performance jet aircraft on a carrier deck. Its implications for training in general are limited by the following considerations: (1) all subjects were experienced pilots, having a median 2,803 hours flying experience, and all had previously flown carrier landings; (2) since all subjects received at least 10 trial flights with motion in the simulator before "training" began, what was under study was not acquisition of skill, but rather what decrement of performance would result from "training" in the no-motion condition after exposure to motion; (3) the "criterion" trials testing was done in the simulator; no "transfer" test to aircraft was conducted; (4) the simulation primarily involved "emergencies" of various kinds rather than "normal" flight.

The 12 experienced pilot subjects were divided into 6 groups of 2 each. The "control" pair flew all trials with motion. The 5 experimental pairs flew 10 initial trials with motion, and then each pair flew a different number of "training" trials without motion. All groups were then tested in "criterion" trials with motion. There were no significant differences between any of the pairs on 3 performance measures taken during the initial 10 trials. Measures taken included pilot and system performance measures during approach and touchdown; and a post-flight attempt by the pilot at identification of which simulated emergency failure regime he had been landing under (there were nine possibilities).

e. Description of Measurements and Ratings:
(1) Pilot performance measures
(2) System performance measures
(3) Terminal flight (touchdown) measures
(4) Recognition of failure regime

f. Experimental Setting/Training Context: laboratory, hands-on

g. Statistical Methods: t-tests; ANOVA

h. Variables Being Manipulated:
(1) Training Device: High fidelity visual flight simulator of high performance, carrier-based jet aircraft, capable of 3 degrees of freedom platform motion.
(a) With motion - "kinesthetic"
(b) Without motion - "static"
Chief variable was number of training trials flown without motion.
(2) Fidelity Levels:

	With Motion	Without Motion
Physical	Medium high	Medium
Functional	Medium high	Medium

(3) Type of Task/Skill Required: operations, cognitive, psychomotor, perceptual, part-task
(4) Task Difficulty: high

i. Stage of Training: skill (experimental only)

j. Trainee Sophistication: intermediate to expert

k. Incorporation of Device into P.O.I.: lock-step

l. User Acceptance or Attitude:
(1) Instructors: not applicable
(2) Students: favorable as measured by questionnaire

m. Use of Instructional Features:
(1) Intensity: intensive
(2) Features used: Number/quality of response; others not specified

1. Authors: Ruocco, Joseph N., Vitale, Patrick A., & Benfari, Robert C.

2. Title: Kinetic Cueing in Simulated Carrier Approaches

3. Source: NAVTRADEVCEN Technical Report 1432-1, 28 April 1965

4. Topic Keywords: Kinetic Cueing ; Flight Simulation ; Carrier Landing Simulation ; Platform Motion .

5. Short Summary: A study of the contribution of kinesthetic cueing via platform motion in simulated training of experienced pilots, finds that in the carrier landing task, the static (no motion) condition degrades performance whereas the motion condition sustains performance on criterion trials tests done in the simulator.

6. Devices: High fidelity visual flight simulator of high performance, carrier-based jet aircraft, capable of 3 degrees of freedom platform motion

7. Institutions:

a. Sponsor: U.S. Naval Training Device Center, Port Washington, NY 11050

b. Performing Organization: Grumman Aircraft Engineering Corporation, Bethpage, Long Island, NY

8. Type of Article: Experiment

a. Number of Groups: 6

b. Description of Groups: All subjects and controls were pilots with median number of 2,803 hours flight experience, and some experience at carrier landings; they were matched on the basis of three performance measures on initial trial "flights" in the simulator with no significant differences between scores

(1) Subjects: 2, 75 training trials; no motion
(2) Subjects: 2, 60 training trials " "
(3) Subjects: 2, 45 training trials " "
(4) Subjects: 2, 30 training trials " "
(5) Subjects: 2, 15 training trials " "
(6) Controls: 2, 75 training trials with motion

c. Tests or Trials/Timing: in-process trials and post-tests

d. Number of Different Types of Measures: 4

c. Authors' Conclusions: The groups trained to the 70% proficiency level displayed positive transfer during later stages of the transfer exercise. The important determinant in transfer appeared to be the amount of training received rather than the nature of the device on which practice was given. It appears that the amount of training has both a positive and negative impact on transfer. It is positive in the sense that more highly-trained students can make better use of feedback and can eventually reach a higher performance level, and negative in that they may have learned the "wrong" lead and/or method of applying lead for the task at hand, and consequently, do poorly at first.

Clear specifications of the objectives of training are required. If, for instance, the objective is merely familiarization, setting criterion levels, rather than providing simply a fixed number of trials, would be wasteful.

b. Results:

(1) Key Data: Figure 5 on p. 13 of the report contains the most important information. Data presented in table below were approximate readings from the graphs:

Percent Hits During Transfer Test as a Function of Trial Block and Device

Machine-Gun Trained Group

Proficiency Level	Block 1	Block 2	Block 3	Block 4
30%	47	39	61	57
50%	45	50	57	72
70%	43	60	60	73
Control	48	55	60	54

Laser Trained Group

Proficiency Level	Block 1	Block 2	Block 3	Block 4
30%	55	48	58	65
50%	50	49	67	53
70%	46	54	54	73
Control	48	55	60	54

(2) Verbal Description:

Training trials to criterion showed no significant differences due to device. The trials-to-criterion for group trained to 70% proficiency were significantly higher than either the 30% or the 50% group.

On the transfer test, significant differences in skill due to device were not demonstrated. All groups improved performance during the course of the 4-block transfer test, showing the test as itself a training session. The accuracy data showed that in the initial transfer test blocks, no trained group was significantly more accurate than the untrained control group (see table above). The groups trained to 70% proficiency, however, regardless of training device, demonstrated significantly greater accuracy at the concluding block of the transfer test. Analysis of "miss" data suggested different learning strategies were being used by the different groups, during the course of the transfer test. There was some evidence of negative transfer from the training devices.

k. Incorporation of Device into P.O.I.: lock-step

l. User Acceptance or Attitude: not discussed

m. Use of Instructional Features:
(1) Intensity: intensive
(2) Features used: not specified

9. Abstract:

a. Study Synopsis: The purpose of this experiment was to evaluate the training effectiveness of two tank gunnery training systems. An additional goal was to determine the level of proficiency which students should reach on the device in order to maximize initial transfer on the main gun. The devices used to simulate tracking and firing of the tank gun were both mounted on the tank: one was a low-power gas laser which represented a shell burst by a red light return from the target; this device also simulated flight time of a real shell fired at a moving target. The second device, a coaxial machine gun, gave higher fidelity to a real tank gun than the laser, in requiring greater safety precautions, making a noise when fired, and making a hole in the target.

Six experimental groups of 22 tank gunnery trainees each were trained by firing the two devices. Three groups were trained on the laser device to proficiency levels of 30, 50 and 70 per cent, separately; the other three groups were trained on the coaxial machine gun to the same respective levels of proficiency. The numbers of trials to criterion for all groups were recorded. Following the training on the simulators, the groups were tested for transfer by firing an actual tank gun. A seventh, control group, in the same phase of training as the subjects, fired the acutal tank gun without prior training on any device. Three measurements were taken of the live-firing transfer test: (1) percentage of hits; (2) evaluation of misses, by type; and (3) speed of fire.

Extensive matching of subjects, and control and counter balancing procedures were undertaken to minimize confounds.

level
(3) Subjects: 22 same, trained to 70% proficiency level
(4) Subjects: 22 same but trained on coaxial machine gun, trained to 30% proficiency level
(5) Subjects: 22 same as (4) but trained to 50% proficiency level
(6) Subjects: 22 same as (4) but trained to 70% proficiency level
(7) Controls: 22 same, given no simulated firing training

c. Tests or Trials/Timing: 1 post-test (tank gun firing)

d. Number of Different Types of Measures: 4

e. Description of Measurements and Ratings:
(1) Number of training trials to criterion
(2) Pct. hits on live-fire tank transfer test
(3) Evaluation of misses on live-fire tank transfer test
(4) Speed of firing on live-fire tank transfer test

f. Experimental Setting/Training Context: Institutional, hands-on

g. Statistical Methods: T-test; ANOVA; Arcsin square root transformation

h. Variables Being Manipulated:
(1) Training Devices:
(a) M60A1/3A102B Laser--see section 6 above
(b) M60A1/M73 Coaxial Machine Gun--see section 6 above
(c) M60A1 Tank Gun (transfer testing device)
(2) Fidelity Levels of Simulators:

	Laser	Coax Machine Gun
Physical	Medium-low	Medium
Functional	Medium	Medium-high

(3) Type of Task/Skill Required: tank gunnery; cognitive, psychomotor, perceptual, part-task
(4) Task Difficulty: medium

i. Stage of Training: familiarization, skill, transition

j. Trainee Sophistication: novice

1. Authors: Rose, A. M., Wheaton, G. R., Leonard, Russell L., jr., Fingerman, P. W., & Boycan, G. G.

2. Title: Evaluation of Two Tank Gunnery Trainers

3. Source: U.S. Army Research Institute Memorandum 76-19, August 1976

4. Topic Keywords: Transfer of Training ; Interference ; Negative Transfer ; Tank Gunnery Training ; Fidelity ; Analytical Models ; Medium-low Fidelity .

5. Short Summary: A study of training of tank gunnery trainees on devices differing in degree of fidelity, followed by transfer trials on real tank guns, yielded no significant differences between devices in training effectiveness, but presents examples of both positive and negative transfer from simulated training.

6. Devices:

a. M60A1/3A102B Laser (trainer): a low-power gas laser mounted in an M73 machine gun bracket in the M60A1 tank. Red-light return represents shell burst; device simulates flight time of real shell fired at moving target.

b. M60A1/M73 Coaxial Machine Gun, single shot mode (trainer): operational machine gun with interrupter mechanism to restrict fire, mounted in the M60A1 tank. Higher fidelity than device a.

c. M60A1 Tank Gun (transfer testing device--actual equipment)

7. Institutions:

a. Sponsor: Army Research Institute

b. Performing Organization: Army Research Institute; American Institutes for Research

8. Type of Article: Experiment

a. Number of Groups: 7

b. Description of Groups:
(1) Subjects: 22 11E10 tank trainees from D Company, 3rd Battalion, 1st Training Brigade at Fort Knox; trained on laser, to 30% proficiency level
(2) Subjects: 22 same, trained to 50% proficiency

(2) Verbal Description: As above; plus: the single reliable effect revealed by the command flight path tracking performances was the consistent superiority of pursuit over compensatory tracking.

c. Authors' Conclusions: The moving airplane attitude presentation yielded reliably worse disturbed attitude tracking than either the conventional moving horizon or its frequency-separated counterpart. This single, unprecedented finding cast doubt upon the validity of the results of numerous experiments in fixed-base and moving-base simulators that have indicated superior performance with moving airplane attitude displays.

The frequency-separated display provides at least equivalent pilot steering performance to that obtained with the conventional moving horizon format.

It is evident that the results of experiments conducted either in fixed-base simulators or in ones providing highly distorted motion cues cannot be trusted if spatial orientation is a central consideration.

Finally, because a within-subject experimental design was employed, and because an internal analysis of the data obtained suggests the likelihood of differential intraserial transfer among displays on the initially presented disturbed attitude tracking task, the results for this task cannot be presented without reservation. A direct comparison of the... (various) presentations employing independent groups of flight-naive subjects is essential, as is a flight investigation of the transition of experienced pilots to the frequency-separated display.

sequence of tasks was counterbalanced.

One of the most important tasks was a disturbed attitude tracking task, designed explicity to reveal differences in performances inherently associated with attitude presentation. The subject was forced to respond directly to visually presented attitude indications that were in conflict with supraliminal vestibular cues of angular acceleration.

b. Results:

(1) Key Data:

Mean Standard Deviation of disturbed attitude tracking error in arbitrary units for two trials by sub-groups of four subjects each on each of four display types across serial positions:

	DISPLAY	TYPE		
Trial	Moving Horizon	Moving Airplane	Frequency Separated	Kinalog
Serial Position One				
1	2.34	2.26	1.76	2.87
2	2.03	1.77	1.27	1.59
Serial Position Two				
1	1.07	2.08	1.20	1.92
2	1.12	1.81	1.01	1.61
Serial Position Three				
1	1.15	1.34	1.92	1.91
2	1.22	1.77	1.33	1.63
Serial Position Four				
1	0.98	2.39	1.28	2.03
2	1.29	1.63	1.32	1.88

Combined reversals and correct responses made with and without knowledge of display type by 16 subjects. Each attempting to recover from four subliminally entered unknown attitudes while using each of three types of attitude presentation.

Display Type	Reversed Responses	Correct Responses	Total Trials
Moving Horizon	14	50	64
Moving Airplane	3	61	64
Frequency Separated	9	55	64

motion.

Study One evaluated the transfer of training from simulator to aircraft by aircraft checkflight maneuvers and trials to proficiency among four groups of pilots: two groups who received simulator training plus aircraft training in proportions prescribed by the regular syllabus, one group who received both aircraft and simulator training, except that their simulator training did not include the final phase of landing to touchdown. Although the graded checkflight scores found all groups roughly equal in performance, the two groups who had not received landing training in the simulator (includes the "aircraft only" group) took more aircraft trial landings to attain proficiency then the other group.

The motion versus no-motion study was confounded by several factors, of which the most important was that some no-motion subjects did in fact receive some training with platform motion. Nevertheless, despite the favor shown by both instructors and pilots to the platform motion feature, there were few practical differences attributable to the addition of platform motion in training as measured by the simulator and these differences washed out when transition was made to aircraft flight.

The study of motion sickness revealed little incidence of motion sickness either with or without platform motion.

b. Results:

(1) Key Data:

(a) Study One (Landing Training):

Group	Simulator Landings	Aircraft Landings to Proficiency
C-1 (N=27)	28	17
C-2 (N=39)	28	28
C-3 (N=10)	0	50
C-4 (N=19)	23 *	37

* Trainer frozen or waveoff indicated at Select Land Flap position in the landing pattern (i.e., no touchdown simulations)

(b) Study Two:

Average Trials to Proficiency

	With-Motion (N=39)	No-Motion (N=11)
Totals for 13 tasks	42.5	53.2

(Study data shows 13 tasks broken down. For most tasks there are small and in some cases significant differences, and in three cases large differences, as follows:)

Abort 4 Engine	1.5	3.0
Abort 3 Engine	2.9	4.9
Holding	4.1	1.7

(2) Verbal Description:

(a) Study One: The Transfer Effectiveness Ratios computed from the landing data show that landing practice in the simulator provides a training benefit under the three different training conditions examined.

(b) Study Two: Simulator training without cockpit motion versus with cockpit motion shows in gene al small significant but not practical benefits from cockpit motion. Individual differences among students had more effect on trials to proficiency than did training method. Later trials to proficiency in the aircraft for four and three engine aborts were not significantly affected by lack of cockpit motion in the simulated training. Both students and instructors subjectively strongly favor the use of platform motion in the simulator.

c. Authors' Conclusions: Study results indicate that simulator practice in landing pattern airwork and the final phase of landing transfers positively to the aircraft. This transfer occurs even though instructor and student pilots universally agreed that the 2F87F does not "handle" like the aircraft during the final phase of landing. Although both students and instructors strongly favor the use of platform motion in the simulator, experimentally it was found that individual differences among students had more effect on trials to proficiency than did the presence or absence of simulated cockpit motion. The addition of

platform motion does significantly improve performance of most tasks, but not with practical importance except in two tasks, three and four engine aborts. These differences washed out in later trails in the aircraft.

1. Author: Semple, Clarence A. Jr.

2. Title: Training Effectiveness Evaluation: Device 1D23, Communication and Navigation Trainer

3. Source: NAVTRAEQUIPCEN 72-C-0209-2, March, 1974; National Technical Information Service AD 766 619

4. Topic Keywords: Transfer of Training ; Flight Navigation ; Flight Communications ; Training Effectiveness .

5. Short Summary: An evaluation of the 1D23 flight communications and navigation training device finds that it enhances navigation skills transferred to aircraft in many aspects, which, however, can only be detected by supplementary performance criteria outside the usual overall 4-point flight performance grade.

6. Devices: Training aircraft used as transfer testing environments:

   a. T-29 and C-114

   b. T-39

7. Institutions:

   a. Sponsor: Naval Training Equipment Center, Orlando FL 32813

   b. Performing Organization: Manned Systems Sciences, Inc., Northridge, CA

8. Type of Article: Experiment (four separate experiments)

   a. Number of Groups: 2 groups in each of 4 experiments

   b. Description of Groups: In each experiment, subjects and controls were matched by aptitude scores and instructor assessments of intangible criteria (e.g., morale). In experiments 3 and 4 they were also balanced by progress in the flight navigation training to that date

      (1) Experiment 1: 23 subjects, 23 controls
      (2) Experiment 2: 23 subjects, 23 controls (same trainees as in Experiment 1)
      (3) Experiment 3: 15 subjects, 15 controls
      (4) Experiment 4: 14 subjects, 14 controls

   c. Tests or Trials/Timing: In-process trials and

post-tests (checkflights)

d. Number of Different Types of Measures: 5

e. Description of Measurements and Ratings:
(1) Standard 4-point Aviation Training Forms and Grading (all experiments)
(2) Supplementary Performance Evaluation: more objective, task-specific measures, used in Experiments 2 and 4
(3) Student questionnaires
(4) Instructor questionnaires
(5) Instructor interviews

f. Experimental Setting/Training Context: institutional, hands-on

g. Statistical Methods: t-tests; factorial analysis of variance; multiple discriminant analysis

h. Variables Being Manipulated:
(1) Training Devices:
(a) Experiments 1 & 3: T-29 and C-114 training aircraft (transfer environment) 1D23 training device
(b) Experiments 2 & 4: T-39 training aircraft (transfer environment) 1D23 training device
(2) Fidelity Levels of 1D23 trainer:
(a) Physical: medium-high
(b) Functional: medium-high
(3) Type of Task/Skill Required: operations; cognitive; procedural; whole-task
(4) Task Difficulty:

i. Stage of Training: introduction, skill

j. Trainee Sophistication: intermediate

k. Incorporation of Device into P.O.I.: lock-step and self- paced (trainees were allowed additional practice on the device on their own time)

l. User Acceptance or Attitude:
(1) Instructors: favorable as assessed by questionnaire
(2) Students: not discussed

m. Use of Instructional Features:
(1) Intensity: assumed intensive
(2) Features used: Sign-in Capability; Number/Quality of Responses; Automated

Demonstration; perhaps Internal Monitoring of Instructional Features; others not specified

9. Abstract:

a. Study Synopsis: This study of the effectiveness of jet flight communication and navigation simulator Device 1D23 in a specific syllabus of instruction was separated into four experiments with the following objectives:

(1) To assess impact of device training on student performance in dead reckoning navigation performance in the T-29 or C-114 aircraft;
(2) Same for student communication and navigation task performance in the T-39 training phase;
(3) Same for increased device training on student performance in dead reckoning navigation performance;
(4) Same for increased device training on student performance in the T-39 training phase.

The first two experiments compared the aircraft (transfer) performances of groups that had received training on the device with groups that had not received training on the device. The last two experiments compared the aircraft performance of groups that received the standard amount of device training with groups that received an additional session on the device.

Groups in each experiment were closely matched by Flight Aptitude Ratings and by Aviation Qualification Test scores, by more subjective factors assessed by instructors (e.g., morale), and, in the later training phases, by progress in the syllabus to that point in the training.

Measurements in all experiments were the standard 4-point Aviation Training Forms and Grading, and student questionnaires, and instructor questionnaires and interviews. In experiments 2 and 4, a supplementary task- oriented performance measure, judged to be more objective, was added to supply greater evaluative sensitivity.

b. Results:

(1) Key Data - Experiment 2

SUMMARY OR PERFORMANCE IMPROVEMENTS RESULTING FROM TRAINER

Measure	Mean Value Untrained Group	Mean Value Trained Group	Chance Difference Probability
No. of No. 2 Needle Reading Errors	.58	.09	.001
No. of Altimeter Reading Errors	.81	.30	.001
No. of Wrong Headings	2.01	.88	.001
No. of Fuel Mgmnt. Errors	.58	.36	.05
Minutes of get on Radial	3.85	2.47	.01
Pct. of time on Radial	59.65	78.37	.001
No. of Missed Calls	2.38	1.65	.05
ETAs, No. Min.s off	1.52	1.08	.01
No. of Voice Comm. Errors	3.77	2.86	.05
No. of Turn Point Errors	1.28	1.06	.05

(2) Verbal Description: In Experiments 3 and 4, no significant differences in performance were detected on any measures.

Experiment 1 yielded conflicting results. Although no significant differences were found between groups in the standard 4-point scoring, instructor opinion strongly supported the effectiveness of the device. For that reason, the supplementary grading criteria, which separated the communications and navigation tasks into 13 sub-tasks with more objective measurement parameters, was employed in Experiment 2 (and 4).

The Key Data for Experiment 2 appear in the table above, which shows the ten measures on which the device-trained group demonstrated significant superiority to the group not trained on the device. Of the other 3 sub-task measures, no

significant differences were found.

As with the other experiments, however, in Experiment 2 there was no significant difference in standard 4-point overall instructor-scored flight grades.

Other results included instructor assessments of device capabilities and deficiencies; the most salient points being the absence of flight stress and criticality in the simulator, the absence of pilot- pacing of activity which is the rule in the airplane, and the lack of static and communications patter which are typical in an airplane. In the area of physical fidelity, a device shortcoming was its nearly exclusive reliance on digital indicators, whereas analog instrumentation predominates in the aircraft.

c. Author's Conclusions: It is felt that reliable conclusions regarding the training effectiveness of Device 1D23 cannot be drawn from flight grades alone. The strength and consistency of instructor opinion data support the conclusion that training in the device has resulted in improvements in virtually every aspect of student confidence and performance in the execution of dead reckoning tasks in an airborne setting; and statistical analysis of supplemental measures indicate that training on the device has resulted in numerous improvements in student performance during T-39 training flights.

Task areas for which moderate or no improvement in student performance was observed following training in the device can be considered as definitions of areas in which the training effectiveness of the device could be further enhanced.

Additional device training, beyond that already incorporated into the syllabus, had no effect upon subsequent aircraft performance in either dead reckoning navigation tasks or performance of airways navigation and communication tasks.

1. Authors: Smith, Russell L., Pence, Gail G., Queen, John E., & Wulfeck, Joseph W.

2. Title: Effect of a Predictor Instrument on Learning to Land a Simulated Jet Trainer

3. Source: National Technical Information Service AD/A-000 586, August 1974

4. Topic Keywords: Predictor Instrument ; Flight Simulator ; Landing Training .

5. Short Summary: An evaluation of a glideslope predictor instrument as a training aid in a simulated landing task found the predictor effective in improving glideslope control performance in the transfer task in the simulator.

6. Devices:

   a. Simulator with CRT display showing 2-dimensional aircraft glideslope position, attitude control, throttle control, and indicators of engine power and airspeed, audio stall alarm, no other controls or displays

   b. Computer-generated analog graphic glideslope predictive display on simulator CRT

7. Institutions:

   a. Sponsor: Air Force Office of Scientific Research , 1400 Wilson Blvd., Arlington, VA 22209

   b. Performing Organization: Dunlap and Associates , Inc., Western Div., 115 So. Oak St., Inglewood, CA 90301

8. Type of Article: Experiment

   a. Number of Groups: 10

   b. Description of Groups:
   (1)-(9) Subjects: 5 Air Force and Navy ROTC students from Los Angeles Area ROTC programs, ages 18-24, little or no flying experience but met A.F. or Navy qualifications for flight training. Randomly selected except balanced between groups for flying experience.
   (10) Controls: 5 same

   c. Tests or Trials/Timing: In-process trials

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d. Number of Different Types of Measures: 2

e. Description of Measurements and Ratings:
(1) Integrated altitude error
(2) Integrated airspeed error

f. Experimental Setting/Training Context: Laboratory, hands-on

g. Statistical Methods: ANOVA; Duncan's multiple-correlation test; rank-correlation

h. Variables Being Manipulated:
(1) Training Devices: as above section 6
(2) Fidelity Levels (for simulator, both predictor-aided and non-predictor-aided):
(a) Physical: medium-low
(b) Functional: medium-low
(3) Type of Task/Skill Required: operations, cognitive, psychomotor, perceptual, part-task
(4) Task Difficulty: medium-high

i. Stage of Training: not applicable (experimental)

j. Trainee Sophistication: novice

k. Incorporation of Device into P.O.I.: not applicable

l. User Acceptance or Attitude: not discussed

m. Use of Instructional Features:
(1) Intensity: intensive
(2) Features used: augmented feedback; number/quality of responses

9. Abstract:

a. Study Synopsis: The primary objective of this study was to explore a predictor instrument's utility as a training aid in a relatively complex, psychomotor task. The task was to control the glideslope in the simulated landing of an aircraft. The simulator consisted of (1) a CRT display of continuous aircraft vertical and forward-and- backward position in relation to an ideal glidepath line drawn on the CRT face; (2) an engine power indicator; (3) an airspeed indicator; (4) an audio stall warning; and (5) throttle.

The predictor used in the experiment was a computer-generated trace line on the CRT, which projected out from the instantaneous aircraft position marker and

showed what the future two-dimensional glideslope of the aircraft would be if the controls were to be held constant from that instant. In the experiment, three different predictive time-spans were used (illustrated by shorter or longer projected lines on the CRT face): 5, 10, and 20 seconds.

A second experimental variable of the predictor was the "adaptive mode", which signified the out-of-tolerance condition under which the predictive trace-line would appear (under ideal operator control input, no trace line appeared). Three levels of adaption were employed in this study: (1) Adaptive Mode 0, in which the predictor trace appeared only when the instantaneous path was out of tolerance; (2) Adaptive Mode 5, in which the trace appeared whenever the path would be out of tolerance as of 5 seconds in the future; (3) Adaptive Mode 10, in which the trace appeared whenever the path would be out of tolerance.

The nine (3 x 3) experimental conditions thus generated were applied to nine groups of subjects consisting of 5 ROTC volunteers age 18-24 each, who had little or no flight experience but had met Air Force or Navy flight qualifications. A tenth, control condition was applied to an equivalent group of 5; groups were randomly selected except balanced by flight experience.

All training and testing took place in the simulator. The controls did not receive any aid from the predictor during training or testing, whereas the experimental subjects received predictor aid during training but not during testing. Test trials were alternated with training trials throughout the experiment.

Performance measurements on the tests were of integrated altitude error (deviations about the ideal glideslope), and integrated airspeed error.

b. Results:

(1) Key Data:
Mean Altitude Error as a Function of Prediction Span and Adaptive Mode:

Prediction Span 5 sec. - error 287
Prediction Span 10 sec. - error 263
Prediction Span 20 sec. - error 218
Adaptive Mode 0 - error 270
Adaptive Mode 5 - error 269
Adaptive Mode 10 - error 225

Reviewer's Note: Figures are approximations from graphs

(2) Verbal Description: In general, with the exception of Condition 2 (prediction span 5 sec., adaptive mode 5), all experimental conditions appeared to be superior to the control condition. Condition 9 (prediction span 20 sec., adaptive mode 10) demonstrated by far the highest level of performance at the start; most of the experimental conditions showed sharp declines in error scores during the first 24 trials.

The table above shows the effect of each variable when averaged over the other variable. For the variable of prediction span, an ANOVA yielded an F ratio of 20.71, significant beyond the .01 level. A Duncan's range test revealed that performance on each of the three prediction spans was significantly different ($p < .05$) from the others. Thus, performance improved significantly on test trials as prediction span during training increased from 5 seconds to 20 seconds.

With regard to adaptive mode, an ANOVA yielded an F ratio of 11.56 which was again significant beyond the .01 level. A Duncan's range test indicated that the 10 second adaptive mode was significantly better than the 0 and 5 modes ($p < .01$). These results indicate, that the sooner the predictor instrument appeared on the operator's display during training, the better the performance on test trials.

A rank correlation between altitude and airspeed error yielded a coefficient of .794. The results of airspeed error were similar to those of altitude error with respect to prediction span and adaptive mode.

c. Authors' Conclusions: Not all predictor displays led to higher performance than the control condition. In general, conditions having the shortest prediction spans and adaptive modes exhibited somewhat poorer performance than the control condition on a number of trials, while the opposite configurations showed consistently superior performance. Perhaps a meaningful explanation for the differential results is related to the concept of "facilitation-interference." Periodically observing the predictor trace at the expense of continuously monitoring the aircraft symbol might have conflicted with control operations and

degraded performance in the cases where the predictor provided only minimal forecasting information (that is, when it appeared more rarely and gave only a brief predictive time-span).

In the present study, not only were mean performances of several predictor groups substantially superior to the control condition, standard deviations were also very depressed, indicating very narrow distributions about high mean performance levels.

Results of this study suggest strongly that the predictor instrument may have considerable utility as a training aid in a wide variety of complex, manual control tasks. Transfer effects appear to have achieved practical, as well as statistical significance. Our data suggest that a more appropriately designed predictor display (with a span of 30 seconds and an adaptive mode of 15 seconds, for example) would have led to an even greater transfer effect than that observed in this study.

1. Author: Spangenberg, Ronald

2. Title: Tryout of a General Purpose Simulator in an Air National Guard Training Environment

3. Source: AFHRL-TR-74-92, December 1974

4. Topic Keywords: Maintenance Training Simulator ; General Purpose Simulator ; Technical Training ; Maintenance Troubleshooting ; Training Effectiveness .

5. Short Summary: A study of the use of a General Purpose Simulator for on-the-job training of experienced technicians found it highly acceptable to trainees, and a performance test indicated it was an efficient training device.

6. Device: EC II General Purpose Simulator for Maintenance Training; simulating APQ Radar System

7. Institutions:

   a. Sponsor: HQ Air Force Human Resources Laboratory (AFSC), Brooks AFB, TX 78235

   b. Performing Organization: Technical Training Division, Air Force Human Resources Laboratory, Lowry AFB, CO 80230

8. Type of Article: Experiment

   a. Number of Groups: 2

   b. Description of Groups:
      (1) Subjects: 11 experienced avianics technicians qualified on the APQ-126 (system being simulated)
      (2) Subjects: 6 same, not qualified on the APQ-126

   c. Tests or Trials/Timing: post-test; questionnaires

   d. Number of Different Types of Measures: 2

   e. Description of Measurements and Ratings:
      (1) Number of component replacements (troubleshooting task)
      (2) Malfunction isolation time (troubleshooting task)

   f. Experimental Setting/Training Context: Field, OJT

   g. Statistical Methods: not specified

c. Authors' Conclusions: The results from the male subjects gave the authors support for their hypotheses. The negative effect of overtraining was significant in transfer, and there was a nonsignificant "trend" toward higher fidelity (in the form of 5 stacks in training rather than 3 stacks) also having some negative effect on transfer.

The authors conclude: "since overtraining may or may not be advantageous in a simulation situation, it is important then to determine what is being overtrained. It would appear that if a strategy is well learned, but not the specifics of the training device, then this is not detrimental to ultimate performance."

The contradictory findings for the females are partially explained by the hypothesis that different hand sizes between males and females may have led to different learning strategies.

b. Results:

(1) Key Data:

AVERAGE TIME (IN SECONDS) ON TRANSFER ON 1ST AND 5TH TRIAL BLOCK, BY TRAINING CONDITION & SEX

		Block 1	Block 5
8 Racks (Control)	- Male	83	50
	- Female	91	59
5 Racks Overtrained	- Male	78	60
	- Female	77	48
5 Racks Not Overtra.	- Male	83	56
	- Female	81	59
3 Racks Overtrained	- Male	81	58
	- Female	83	51
3 Racks Not Overtra.	- Male	76	53
	- Female	81	53

$p \leq .05$ for superiority of male controls over male simulator- trained groups by Block 5

(2) Verbal Description: All groups--experimental and control--showed improvement over the 5 blocks of transfer trials. The control groups showed an initial inferiority in Trial 1 and then began to catch up.

(a) Among male subjects: the "overtrained" subjects trained on 5 racks showed the least improvement on the transfer trials, and performed most poorly on the final block. The "not overtrained" group trained on 3 racks improved the most, and performed best among the trained groups on the final block. The other two groups' relative performance also accorded with the hypotheses propounded above; the "overtrained" 3 stack group was inferior to the "not-overtrained" 5 rack group. However, all the experimental groups were outperformed by the control group, which improved by far the most over the 5 transfer blocks, and finished with the best performance on the final block.

(b) Among female subjects: contradictory trends were evident. The "overtrained" 5-rack group improved and finished the best during transfer; the "overtrained" 3-rack group was second in improvement and final performance; the control group lagged far behind with the "not- overtrained" 5-stack group.

equipment. These overlearned inappropriate responses can cause negative transfer. The authors suggest that criterion performance levels during training be used to cut off training at the optimal point, and to minimize overlearning and negative transfer.

Secondly, aside from the cost disadvantages of achieving high realism, the face validity of a simulator may be deceptive as long as it is not 100% identical to the actual equipment--which by definition it cannot be. The more highly realistic a device, the more misleading any inappropriate elements embedded in it may be. In some cases, a lower fidelity simulation, affording a more generalized response during learning, may be less likely to overtrain the student into bad habits, because in transferring to the actual equipment, he or she will less likely identify, and thus confuse, aspects of the simulator with aspects of the actual equipment.

An experiment in a simple perceptual-motor task was used to demonstrate these principles. Equal numbers of male and female experimental subjects were trained to perform a collating operation removing sheets of paper from stacks in a machine. In full operation the machine would produce 8 stacks. Subjects were trained by collating either 3 or 5 stacks, and tested for transfer by collating 8 stacks. Time of training was also a factor, in that each group was subdivided into "overtrained" and "not overtrained" groups (the "overtrained" were given additional training trials beyond those required to reach a criterion performance level).

In the transfer condition, five blocks of trials were given. A control group which had been given no prior training in the task also performed 5 blocks of the transfer task. The one measure taken for all subjects was time to complete the task.

g. Statistical Methods: not specified

h. Variables Being Manipulated:
(1) Training Devices: as in section 6 above; training simulations varied as follows:
(a) "Overtrained" on 3 racks
(b) "Overtrained" on 5 racks
(c) "Not overtrained" on 3 racks
(d) "Not overtrained" on 5 racks

(2) Fidelity Levels:

	3 Racks	5 Racks
Physical:	Medium High	Medium High
Functional:	Medium High	Med.high to High

(3) Type of Task/Skill Required: Collating; psychomotor; perceptual; part-task
(4) Task Difficulty: Low

i. Stage of Training: introduction, skill (not strictly applicable--experimental only)

j. Trainee Sophistication: Novice; but the task was so simple they were probably expert by the time experiment was completed

k. Incorporation of Device into P.O.I.: lock-step (not strictly applicable--experimental only)

l. User Acceptance or Attitude: not discussed

m. Use of Instructional Features: not applicable

9. Abstract:

a. Study Synopsis: This paper discusses two principal issues in the optimization of simulator training, and describes an experiment to illustrate the hypotheses which are advanced.

Central to the discussion is the distinction between optimal and maximal, especially as a reflection of the possible deterioration of performance due to negative transfer when a simulator is overused. The common-sense validity of designing a simulator to resemble actual equipment as closely as possible, and the validity of training students on the simulator as long as they continue to learn on it, are both brought into question.

First of all, increasing time spent learning on the simulator tends to overtrain all responses, including the ones that may be inappropriate on the actual

1. Authors: Weitz, Joseph., & Adler, Seymour

2. Title: The Optimal Use of Simulation

3. Source: Journal of Applied Psychology, 1973, 58(2), 219-224

4. Topic Keywords: Simulation ; Negative transfer ; Overtraining ; Simulator Fidelity .

5. Short Summary: Due to negative transfer, a result of overtraining, the optimal amount of simulator practice and the optimal degree of simulator fidelity may be much less than is usually assumed under the "more is better" principle.

6. Devices:

a. T-8 Thomas table-top collater with 8 operational racks (transfer device)

b. Same but with only 3 or 5 racks operating (training device)

7. Institutions:

a. Sponsor: Air Force Office of Scientific Research , Air Force Systems Command

b. Performing Organization: Department of Psychology, New York University

8. Type of Article: Experiment

a. Number of Groups: 10 (5 male, 5 female)

b. Description of Groups:
(1)-(4) Subjects: 10 males each
(5) Control: 10 males
(6)-(9) Subjects: 10 females each
(10) Controls: 10 females

c. Tests or Trials/Timing: Post-test

d. Number of Different Types of Measures: 1

e. Description of Measurements and Ratings: Time to complete task

f. Experimental Setting/Training Context: laboratory, hands-on

instructor.

The research described in this report was directed to improving the laboratory model, maximizing the transportability of the software to new microprocessors, and augmenting the software to allow Navy instructors to manage the system.

Capabilities of the device are enumerated and data on the system's reliability and maintainability are also provided.

b. Results: Results of informal preliminary experimental studies with advanced prototypes of the GMTS in training maintenance troubleshooting were generally positive. In one of the experiments cited, students trained on the GMTS were field tested for transfer on the actual equipment with encouraging results.

c. Authors' Conclusions: The GMTS hardware and software have been refined and documented to meet the research objective of providing the intensive training desired at low cost. Testing and evaluation of the device in the school environment are scheduled.

f. Experimental Setting/Training Context: field testing in a naval school setting

g. Statistical Methods: not specified

h. Variables Being Manipulated:
   (1) Training Devices: GMTS as in section 6 above
      (a) Simulating Fleet communications System, a multi-equipment system for radio communications
      (b) Simulating AN/APA-66 radar repeater
   (2) Fidelity Levels:
      (a) Physical: Medium-low (2 dimensional microfiche projections of equipment)
      (b) Functional: Medium-high
   (3) Type of Task/Skill Required: Maintenance troubleshooting; cognitive, psychomotor; whole-task, part-task
   (4) Task Difficulty: Medium-high

i. Stage of Training: not specified

j. Trainee Sophistication: not specified

k. Incorporation of Device into P.O.I.: not specified

l. User Acceptance or Attitude: not specified

m. Use of Instructional Features:
   (1) Intensity: not specified
   (2) Features used (available): Restart/Resequence Capability; Malfunction Selection; Sign-in capability; Number/Quality of Responses; Next Activity Features; Automated Demonstration

9. Abstract:

a. Study Synopsis: This report briefly reviews the development, from a laboratory model, of a working Generalized Maintenance Training simulator. The report details hardware and software features of the device, a computer-based simulator that automatically selects malfunctions and displays high-resolution color images of the actual maintenance testing equipment. The student can rapidly access close-up views of any section of the equipment (and conversely, "zoom out" again) and can interact with the displayed switches by touching desired switch settings with a small stylus. The device has the capability to simulate a wide variety of electronic equipment and to present a multiplicity of maintenance set-up, systems assessment, and troubleshooting problems to be selected by the

1. Authors: Towne, Douglas M., & Munro, Allen

2. Title: Generalized Maintenance Trainer Simulator: Development of Hardware and Software - Final Report

3. Source: NPRDC TR 31-9, April 1981

4. Topic Keywords: Maintenance Training Simulation ; Troubleshooting ; Generalized Simulator .

5. Short Summary: A review of preliminary experimental studies of a generalized maintenance training simulator designed to provide intensive training in set-up, troubleshooting, and system assessment for a variety of electronic equipment. Results indicate that the device is ready for formal testing and evaluation in a Navy school.

6. Device: Generalized Maintenance Training Simulator , a computer-based simulator that automatically selects malfunctions and displays high-resolution color images of the equipment. Student interacts by touching with a small stylus.

7. Institutions:

   a. sponsor: Navy Personnel Research and Development Center, San Diego, CA 92152

   b. Performing Organization: Behavioral Technology Laboratories, University of Southern California, Redondo Beach, CA 92152

8. Type of Article: Experiment (Two informal preliminary field tests are cited--Rigney, Towne, King, & Moran, 1978; and Rigney, Towne, Moran, & Mishler, 1980

   a. Number of Groups: 2

   b. Description of Groups:
      (1) Subjects: 20 radio communications students
      (2) Controls: 10 radar students

   c. Tests or Trials/Timing:
      (1) 35 problem trials
      (2) 33 problem trials

   d. Number of Different Types of Measures: not specified

   e. Description of Measurements and Ratings: not specified

The simulator was of low physical and functional fidelity, consisting of a sheet with erasable material covering information for each item. The examinee attempted to solve the problem by erasing as few items as possible to location of the fault.

b. Results:

(1) Key Data:

Rank Order Inter-test Correlations for Five Performance Variables (N=14)

Test Score Category	Simulated x Actual
No. of Steps	-.32
No. of Correct Steps	.14
No. of Incorrect Steps	-.19
Total time	-.50
Tester's Rating	-.35

(2) Verbal Description: Four of the five scored variables were found to be negatively related between tests (see above).

Overall troubleshooting strategy was apparently influenced by the test format since results showed that only 1 of the 14 examinees selected the same initial troubleshooting step on both his actual and simulated test.

Correlations were also made between these test scores and the overall performance achievement scores of students for the equipment phase of the same course. High significant correlations were found (.55) between the actual equipment test score and the overall performance score, whereas the correlation with the simulated test and the overall performance score was -.36.

c. Author's Conclusions: The simulated performance measure employed in this investigation did not provide a valid estimate of proficiency on the identical task requiring actual performance. The evidence strongly suggests caution in replying upon simulated tests, even those with considerable face validity, without empirical validation.

(5) tester's rating;
(6) number of parts replaced

f. Experimental Setting/Training Context: institutional, hands-on

g. Statistical Methods: Rank order correlation

h. Variables Being Manipulated:
(1) Training Devices: as above, section 6
(2) Fidelity Levels:

	Simulator	Actual Equip.
Physical	Low	Highest
Functional	Low	Highest

(3) Type of Task/Skill Required: maintenance, cognitive, psychomotor, perceptual, part-task
(4) Task Difficulty: Medium-high

i. Stage of Training: Skill

j. Trainee Sophistication: not specified; presumed intermediate

k. Incorporation of Device into P.O.I.: lock-step (not instructional)

l. User Acceptance or Attitude: not discussed

m. Use of Instructional Features: not applicable

9. Abstract:

a. Study Synopsis: As part of a larger research effort to develop a practicable system for validly assessing performance skills in various Navy technical ratings, this study investigated how people perform on an actual equipment performance test as compared with how they perform on the identical task in simulated performance format.

The task to be performed was a troubleshooting to locate a faulty resistor in a radio receiver. Performance measures taken included: (1) number of steps; (2) number of correct steps; (3) number of incorrect steps; (4) total time; (5) tester's rating; and (6) number of parts replaced. 14 students in an experimental Naval Electronics Technician training course were tested with both actual equipment and a simulator. The simulated and actual equipment tests were administered in courter-balanced order with approximately 3 weeks between the first and second testing.

1. Author: Steinemann, John H.

2. Title: Comparison of Evaluations Obtained from Assessment of Proficiency on Simulated and on Actual Performance Tasks

3. Source: Naval Personnel Research Memo SRM 67-1, July 1966

4. Topic Keywords: Electronics Troubleshooting ; Proficiency Testing ; Simulation ; Low Fidelity .

5. Short Summary: A comparison of a paper and pencil simulation of a troubleshooting task with the same task performed on actual equipment showed the actual equipment trial superior as an evaluator of proficiency.

6. Devices:

a. Simulator: Paper and pencil test sheet with covering material which when erased reveals information given for each item.

b. Actual Equipment: superheterodyne radio receiver

7. Institutions:

a. Sponsor: U.S. Naval Personnel Reseatch Activity, San Diego, CA

b. Performing Organization: U.S. Navy Training Research Laboratory, U.S. Navy Personnel Research Activity, San Diego, CA

8. Type of Article: Experiment

a. Number of Groups: 1

b. Description of Groups: Subjects: 14 students in an experimental Navy Electronic Technicians training course

c. Tests or Trials/Timing: 2 (1 test on each device for every member of group, in counterbalanced order)

d. Number of Different Types of Measures: 6

e. Description of Measurements and Ratings:
(1) number of steps;
(2) number of correct steps;
(3) number of incorrect steps;
(4) total time;

simulator was designed to achieve were accomplished by all personnel. Motivational similarity--a feeling or attitude on the part of the student of functional similarity between the real equipment and the simulator-- was also achieved. Use of a GPS provides a reasonably economical simulation capability when a variety of simulations are required in a training program or when low student flow permits sharing of GPS capability among different programs.

evaluated the device. Measures of test performance were number of parts replaced, and time to isolate the malfunction.

* Reviewer's Note: It is my inference that the testing was done on the GPS--author failed to make explicit.

b. Results:

(1) Key Data: Learning On The GPS:

Learning Indicator	Qualified Personnel (yes/total)	Unqual. Personnel (yes/total)
Did you learn purpose of controls?	11/11	6/6
Can you interpret normal/malfunction operation?	11/11	6/6
Can you perform system self checks?	9/11	6/6
Can you isolate malfunctions?	10/11	5/6
Mean number replacements (units)	1.43	1.71
Median of average malfunction isolation time (minutes)	1.76	2.82

(2) Verbal Description: A performance test showed a high level of achievement using the GPS. Of particular note is the programmed capability provided by the simulator enabling training in the isolation of selected malfunctions. Experienced mechanics given the write-up averaged less than two minutes to identify and correct each malfunction in the simulation. Time to clear a malfunction on the flight line would average over an hour per malfunction because of the need to actually remove the faulty component, and probably slightly longer when training is also being accomplished.

The recommendations of the experienced mechanics indicate that the GPS is usable for field training. Student and instructor acceptance of the GPS was indicated by the questionnaire data; experienced mechanics generally indicated that training could be performed easier and faster on the GPS.

c. Author's Conclusions: This report indicates the efficiency and effectiveness of the simulation of an APQ 126 Radar System by the GPS in a field training environment. Data colleced from field use indicated that psychological realism was economically captured in the simulation of the APQ 126. The goals which the

h. Variables Being Manipulated:
(1) Training Devices: as above, section 6
(2) Fidelity Levels:
(a) Physical: medium-low
(b) Functional: medium-low
(3) Type of Task/Skill Required: maintenance, troubleshooting, cognitive, psychomotor, part-task
(4) Task Difficulty: Medium-high

i. Stage of Training: Group 1, skill; Group 2, transition

j. Trainee Sophistication: intermediate to expert

k. Incorporation of Device into P.O.I.: lock-step

l. User Acceptance or Attitude:
(1) Instructors: highly favorable as measured by questionnaire
(2) Students: same

m. Use of Instructional Features:
(1) Intensity: intensive
(2) Features used: Augmented feedback; Malfunction selection; number/quality of responses; others not specified

9. Abstract:

a. Study Synopsis: This study of the EC II General Purpose Simulator endeavored to evaluate the acceptability and efficiency of the device in providing on-the-job skill training to Air National Guard maintenance technicians. The GPS had already been shown cost-effective in a technical training resident school environment. The GPS has great program flexibility to simulate a wide variety of equipment, at the sacrifice of physical similarity to the specific equipment being simulated. Aspects of functional dissimilarity, such as augmented feedback and varying the part-task sequence, help to make the GPS superior to actual equipment as a trainer. In this study, the GPS was used to simulate the APQ-126 Radar System.

Eleven of the subjects of this study were qualified on the APQ-126 system being simulated; nine were not. Skill levels and experience were generally higher among the experienced subjects.

All subjects were given troubleshooting training on the simulator, tested for troubleshooting isolation on the simulator,* and given questionnaires by which they

1. Authors: Weitzman, Donald O., Fineberg, Michael L., Gade, Paul A., & Compton, George L.

2. Title: Proficiency Maintenance and Assessment in an Instrument Flight Simulator

3. Source: Human Factors , 1979, 21(6), 701-710

4. Topic Keywords: Instrument Flight ; High Fidelity ; Proficiency Maintenance .

5. Short Summary: An instrument flight training high-fidelity simulator is shown effective in maintaining and even improving the instrument flight proficiency of experienced Army helicopter pilots.

6. Devices: High Fidelity Helicopter Instrument Flight Simulator 2B24

7. Institutions:

a. Sponsor: Deputy Chief of Staff for Operations, Aviation Office, Department of the Army

b. Performing Organization: Army Research Institute , Alexandria VA 22333, and Aviation Group, 101st Airborne Div., Ft. Campbell, KY

8. Type of Article: Experiment

a. Number of Groups: 3

b. Description of Groups:
(1) Subjects: Two groups of 12 each fully qualified combat-ready Army helicopter pilots
(2) Controls: One group of 12, same

c. Tests or Trials/Timing: Pre-test and Multiple Post-tests

d. Number of Different Types of Measures: 2

e. Description of Measurements and Ratings:
(1) Performance Measures (ratings by Instructor-Pilot observers):
(a) Checkrides in Aircraft, Instructor-scored, scored 50% by procedural knowledge and 50% by flight control performance: three post-tests in addition to "base-line" pretest
(2) Supervisor Ratings: None except as implied by scoring of Performance Checkrides

(3) Pilot questionnaires

f. Experimental Setting/Training Context: Experimental

g. Statistical Methods: analysis of variance; Tukey's HSD test; trend analyses; product-moment correlation coefficient; regression methods

h. Variables Being Manipulated:
(1) Training Device: Helicopter Instrument Flight Simulator 2B24
(2) Fidelity Levels: High
(3) Type of Task/Skill Required: Instrument Flight of UH-1H helicopter; perceptual, psychomotor, part-task
(4) Task Difficulty: High

i. Stage of Training: Maintenance of skills

j. Trainee Sophistication: High (qualified pilots)

k. Incorporation of Device into P.O.I.: Lock-step

l. User Acceptance or Attitude: Very good as measured by questionnaire

m. Use of Instructional Features:
(1) Intensity: Not specified, presumably intensive
(2) Features used: Not specified

9. Abstract:

a. Study Synopsis: Evidence from training of commercial aircraft pilots indicated that instrument flight simulation training can help maintain real-aircraft instrument flight proficiency. In the present study, an experiment was conducted over a 9-month period with experienced Army helicopter pilots to test the transfer of simulation training to real aircraft performance, and additionally to determine the effectiveness of testing on the simulator to assess instrument flight proficiency.

Equal numbers of high skill and low skill experienced pilots were divided equally into three groups of 12 members each: (1) those to be trained solely in the high fidelity instrument flight simulator 2B24; (2) those to be trained solely on the aircraft, UH-1H helicopter; (3) those to receive a mix of training between simulator and aircraft. Each group was tested

in checkrides on the simulator before and at the conclusion of the experimental training period; and on the real aircraft before, twice during, and once at the conclusion of the experimental training period. All pilots also answered a questionnaire eliciting their judgement as to the effectiveness of the training.

The results appeared to support the hypothesis, that simulator training could maintain and even improve the instrument flight performance among experienced pilots. In fact, the simulator-trained pilots performed significantly (though only slightly) better than the aircraft-trained pilots on the checkrides in the aircraft. Furthermore, the improvement of initially low- skill pilots during the training brought them nearly level with the high-skill pilots on the final checkride.

The high correlation between final aircraft checkride performance and the final simulator checkride performance among all pilots implies the value of the simulation testing in assessing the instrument flight proficiency of experienced pilots.

b. Results:

(1) Key Data:

INFLIGHT CHECKRIDE PERFORMANCE SCORES
BY SKILL LEVEL AND TRAINING CONDITION

	Baseline	1st	2nd	3rd
Low Skill Device 2B24	58	68	80	79
Low Skill Combined	61	72	73	75
Low Skill Inflight	62	61	70	70
High Skill Device 2B24	81	79	83	81
High Skill Combined	80	79	80	79
High Skill Inflight	87	69	75	80

Simulator-trained advantage over inflight-trained is significant at p 0.05

Combined-trained not significantly different from either of other two training conditions (p 0.05)

(2) Verbal Description: Simulator training maintained and in some cases improved real-aircraft checkride performance of pilots, particularly of those initially less skilled in instrument flight. Checkride performances of simulator-trained pilots was superior to that of aircraft-trained pilots in the tested areas of instrument flight. There was high correlation between checkride performance in the simulator and checkride performance in the aircraft. Questionnaires revealed high acceptance of the simulator among those who received solely simulator training.

c. Authors' Conclusions: The results are consistent with the record of commercial aviation which has shown that high fidelity simulators can provide an effective means of providing training for highly qualified pilots. However, it should be emphasized that the effectiveness of any training device depends upon how it is used.... The evidence of transfer in the present study may well be attributed to the training program rather than simulator design alone. It is possible... that if inflight training is conducted with as much structure and control as can occur with simulator training, some evidence of additional benefits might be found.

1. Authors: Wheaton, George R., & Mirabella, Angelo

2. Title: Effects of Task Index Variations on Training Effectiveness Criteria

3. Source: Technical Report: NAVTRAEQUIPCEN 71-C-0059-1, October 1972

4. Topic Keywords: Task Analysis ; Quantitative Task Indices ; Training Effectiveness ; Transfer of Training .

5. Short Summary: This study provides some validation of a set of quantitative task indices as predictors of performance of an operational task, in terms of speed and accuracy.

6. Devices: Synthetic sonar trainer in three basic configurations, according to the number of controls and indicators presented: simple, intermediate, and complex, plus nine additional sub-configurations.

7. Institutions:

   a. Sponsor: Naval Training Equipment Center, Orland, FL 32813

   b. Performing Organization: American Institutes for Research

8. Type of Article: Experiment and Field evaluation

   a. Number of Groups: 12

   b. Description of Groups:
      (1) Subjects: 5 paid male university students from Washington, DC metropolitan area
      (2)--(12) 5 each, same

   c. Tests or Trials/Timing: 15 in-process trials, plus 10 post-trials for 5 of 12 groups. Field evaluation consisted of structured interviews of experienced instructors.)

   d. Number of Different Types of Measures: 3

   e. Description of Measurements and Ratings:
      (1) time to perform task,
      (2) errors of omission,
      (3) errors of commission,
      (4) (for Field Evaluation): estimates provided by experienced instructors in ratio form.

f. Experimental Setting/Training Context: Laboratory, hands-on

g. Statistical Methods: ANOVA; single variable regression analysis; product-moment correlation

h. Variables Being Manipulated:
(1) Training Devices: as above. Additionally, device training trials were varied according to whether every feedback light worked, none worked, or every third one worked.
(2) Fidelity Levels:
(a) Physical: medium to high (varied)
(b) Functional: low to high (varied)
(3) Type of Task/Skill Required: operations; psychomotor; perceptual; procedural; part-task
(4) Task Difficulty: medium

i. Stage of Training: introduction, familiarization, skill, experimental

j. Trainee Sophistication: novice

k. Incorporation of Device into P.O.I.: not applicable

l. User Acceptance or Attitude: not discussed

m. Use of Instructional Features: not specified

9. Abstract:

a. Study Synopsis: The purpose of this study was to determine the relationships between systematic variations in quantitative task characteristic indices were developed (e.g., "LV--the link value reflecting the relative strength of the sequence of use among the various controls and displays. As used here it is the sum of the products of the number of times a link is used, and the percentage of use of the link.") A simulated sonar training device was used in 12 different configurations ranging from simple to complex, which provided variation in all the indices. Twelve groups of five randomly selected university students, one group for each configuration, performed 15 trials of a set-up procedure on the training equipment. Measures of time taken to complete the task, and number of errors of omission and commission were recorded during these trials. 5 of the 12 groups proceeded subsequently to take a transfer test in which the same measures were taken.

A second part of the study evaluated the appropriateness of the task index criteria via structured interviews with experienced sonar instructors in the field.

b. Results:

(1) Key Data:

INTERCORRELATIONS FOR TASK INDEX VALUES AND MEAN PERFORMANCE TIMES ACROSS TRIAL BLOCKS FOR THE LABORATORY TASKS *

Task Indices	Trial Blocks 1	2	3	4	5	6	7
MAIN	73	81	83	86	88	94	88
CNTG	78	82	84	86	90	91	86
TA	77	82	85	87	91	94	88
CONT	66	72	80	83	87	90	83
DISP	65	71	68	72	76	83	74

INTERCORRELATIONS OF TASK INDEX VALUES AND MEAN ERRORS ACROSS TRIAL BLOCKS FOR THE LABORATORY TASK *

Task	Trial Blocks 1	2	3	4	5	6	7
MAIN	59	28	41	57	48	73	18
CNTG	65	46	58	69	66	86	36
TA	63	39	51	64	59	81	28
CONT	46	19	46	61	53	69	17
DISP	58	32	34	46	43	78	14

* Decimal points have been omitted from coefficients for clarity. With 10 degrees of freedom $r = .708$, p $.01$ $r = .576$, p $.05$

MAIN - the number of responses comprising the main or dominant procedural sequence in an operations flow chart.

CNTG - the number of responses comparising the auxiliary or contingency procedural sequences.

TA - the total number of responses (actions) comprising the procedural sequence in an operations flow chart. It is the sum of MAIN and CNTG.

CONT - the total number of different controls manipulated during performance of a subtask.

DISP - the total number of different displays referenced during the performance of a subtask.

(2) Verbal Description: Variations in performance due to type of task were clearly seen. Correlation of task indices with mean performance time at each trial block were in general highly consistent (see tables above). It was found that the strength of correlation between task indices and performance grew with the number of trials--i.e., as learning increased, the correlation became stronger.

In the transfer task, it was found that error was proportional to the distance (along a similarity dimension) between interpolated and transfer tasks.

The findings in the field, through interviews with instructor personnel, tended to correlate well with the laboratory data.

c. Authors' Conclusions: Complete statistical analysis of the results showed that the multivariate approach is essential--i.e., individual task indices did not appear capable of predicting performance on the training devices. Rather, collections of indices, with perhaps specific, but as yet unidentified patterns of features, are crucial. Moreover, there is some hint in the results that these patterns may depend upon training stage.

In addition to implying that predictor patterns may vary with stage of training, the results also imply that criterion patterns may be simularly influenced. Thus, the designer may have to ask, not whether indices relate to training effectiveness, but what patterns of indices relate to what criterion of effectiveness at what stage of training. These are questions which the

present research cannot answer.

Results from the transfer trials suggest that operators trained on synthetic devices, when transferred to field devices, might pay a price in speed, which is not readily mitigated, although conceivably they could attain a satisfactory level of accuracy.

The current research effort has supported the feasibility of relating quantitative indices of equipment design to performance, at least for the restricted set of indices and trainer stacks examined in the present study. The effort has also supported the feasibility of predicting transfer effects from equipment design indices.

1. Authors: Wheaton, George R., Mirabella, Angelo, & Farina, Alfred J. Jr.

2. Title: Trainee and Instructor Task Quantification: Development of Quantitative Indices and a Predictive Methodology

3. Source: NAVTRADEVCEN Technical Report 69-C-0278-1, January 1971

4. Topic Keywords: Quantitative Task Indices ; Task Quantification ; Quantitative Task Anlaysis .

5. Short Summary: A preliminary development of quantitative task indices which were applied to analysis of training devices and to post-dictive predictions of trainee learning performance was reported. The study demonstrated the feasibility of the methods used and tentative predictive validity of some of the derived indices. The desirability of further development was indicated.

6. Devices:

a. In application of methodology to training devices: 3 Naval surface sonar trainers

b. In post-dictive prediction: various devices (unspecified) in 22 experiments

7. Institutions:

a. Sponsor: Human Factors Laboratory, Naval Training Device Center, Orlando, FL 32813

b. Performing Organization: American Institutes for Research , Silver Spring, MD

8. Type of Article: Analytical

9. Abstract:

a. Study Synopsis: This study constituted an initial step in an exploratory program aimed to develop quantitative indices for the task dimension of training devices. This first study undertook to: (1) compile an initial set of quantitative indices; (2) determine whether these indices could be used to describe a sample of trainee tasks and differentiate among them; (3) develop a predictive methodology based upon the indices; and (4) assess that methodology using studies in the literature.

(1) Compilation:

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(` Generic Indices consisted of 29 separate measures drawn from several domains. The two most important domains of indices developed were Siegel's Display Evaluative Index (DEI)--a dimensionless measure of the effectiveness with which information flows from displays via the operator to corresponding controls--and the Panel Lay-Out and Task Type Indices (Fowler et.al., 1968), which can vary independently of the DEI. Seven other generic indices were also developed.

(b) Specific Indices; within this set were indicies specific to surveillance trainers and to certain sub-tasks within those trainers.

(2) Device Task Description and Differentiation. Indices were applied to three Naval surface sonar trainers on four training sub-tasks: set-up, detection, localization, and classification of targets.

(3) The predictive method was an adaption of the standard multiple regression model. Mean task scores replaced the usual individual criterion scores, and quantitative task index values were used as predictor scores.

(4) Predictions were applied to 21 studies (22 experiments) in the literature. The DEI and the Panel Lay-Out Index could not be applied to these studies. However, five other task characteristics rating scales (out of a total of 18 that were analyzed) were used to predict the criterion performance of percent-time-on-target (% T.O.T.) after 5, 10, and 15-minute intervals of practice (the percent time-on-target was a measure common to all the experiments under study).

b. Results:

(1) Key Data (from the post-directive prediction phase):

Multiple Correlations, Performance to Task Indices

Criterion/Time-in-Training	Multiple R	p
Set 1 Indices		
% TOT / 5 min.	.82	<.01
% TOT /10 min.	.74	<.05
% TOT /15 min.	.64	n.s
Set 2 Indices		
% TOT / 5 min.	.63	<.10
% TOT /10 min.	.71	<.10
% TOT /15 min.	.69	<.05

(2) Verbal Description:

(a) Relevant to the Device Task Description and Differentiation phase, need for revision and refinement of most of the indices became apparent. The specific indices, in particular, seemed inconclusive or to be of limited value. Several of the miscellaneous generic indices were easy to apply and generated data of some interest. However, the Display Evaluation Index appeared highly useful, as it possessed diagnostic value and was intuitively satisfying, varying in accordance with subjective impressions of sub-task difficulty (for example, it gave a low value for the object classification sub-task, which reflected the poor classification performance which has been reported in sonar surveillance (Levy & Mirabella, 1968).

(b) Post-dictive predictions showed some high correlations between trainee performance a combined set of five indices when applied to an early stage of training. The table Set 1 above shows the multiple correlations of these indices and trainee percent time on target after 5, 10, and 15 minutes of training; the table shows both a decrease in R and a decrease in significance of the data as training progressed.

Another combined set, shown as Set 2 above, showed stronger correlations at interim stages of training, though its correlation at the initial stage was lower.

c. Authors' Conclusions: An overall appraisal of the

findings of the regression analyses indicates that the criterion measures used in the post-diction studies are of two distinct types. Initial level of performance, the first type, appears to be predicted most efficiently by descriptors which relate to features of the task per se. At initial levels of performance, the training variables used in the studies have had little if any impact. Dominant factors at this stage are probably aspects of the task itself and the abilities of the subjects. It is conceivable that the bulk of the residual variance in the initial performance predictions resides in the subject factor.

At interim training levels, predictive efficiency of the majority of the predictors declines. A potential explanation for this would be the increasing impact of whatever training variables are in effect plus the interaction of these variables with subject characteristics.

The problems and limitations of the post-diction are many and should not be slighted. The attrition experienced as the search went on for suitable studies placed a decided limitation on how far the results of the regression analysis may be generalized.

The development should proceed in three directions. First, refinement of the ratings scales must be undertaken. Second, attention must be given to development of training technique indices; such indices may aid in the prediction of advanced levels of proficiency. Third, the types of indices employed in the present study must be applied to actual training devices for which performance criteria are available.

This study has demonstrated the feasibility of using a variety of quantitative indices to describe salient characteristics of the trainee sub-tasks found in surveillance system training devices.

Results of the post-diction study were encouraging, being obtained in spite of the fact that the major indices of interest (DEI) and panel lay-out could not be employed, and that differences between groups of subjects (a violation of the predictive model) could not be avoided.

1. Authors: Wheaton, George R., Rose, Andrew M., Fingerman, Paul W., Leonard, Russell L. Jr., & Boycan, G. Gary

2. Title: Evaluation of Three Burst-on-Target Trainers

3. Source: U.S. Army Research Institute Memorandum 76-18, August 1976

4. Topic Keywords: Burst-on-Target ; Tank Gunnery Training ; Transfer of Training ; Training effectiveness ; Fidelity .

5. Short Summary: An evaluation of three different training devices that simulate the burst-on-target tank gun firing task finds the three roughly equal in effectiveness, although differing in complexity, physical fidelity, and handling characteristics. The relative superiority of the 17-4M on some indices may be due to the role of instrtuctors.

6. Devices:

a. (Control Group Practice Firing and Transfer Testing Device): 3A102B laser device in M60A1 tank

b. 17-4 "Green Hornet", a relatively simple Burst-on-Target simulator

c. 17-4M, a version of the 17-4 modified for the study to improve versatility, instructional capability, and ease of handling controls

d. 17-B4 Conduct-of-Fire Trainer, a complex and more physically realistic device

7. Institutions:

a. Sponsor: U.S. Army Research Institute for the Behavioral and Social Sciences, 5001 Eisenhower Avenue, Alexandria, VA 22333

b. Performing Organization: USARI and American Institutes for Research

8. Type of Article: Experiment

a. Number of Groups: 4

b. Description of Groups:
(1) Subjects: 18 tank gunnery trainees in Army Advanced Individual Training

1. Author: Adams, Jack A.

2. Title: On the Evaluation of Training Devices

3. Source: Human Factors , 1979, 21(6), 711-720

4. Topic Keywords: Transfer of Training Evaluation ; Rating Method Evaluation ; Laws of Learning ; Flight Simulation .

5. Short Summary: The author questions the usefulness of conventional transfer of training studies and pilot ratings in the evaluation of flight simulators. He proposes that scientific psychological principles, coupled with knowledge of the success of predecessor devices, may provide more satisfactory evaluative tools.

6. Devices: none described. Studies are cited in which the School Link Trainer and the SNJ simulator and other flight training devices were used.

7. Institutions:

a. Sponsor:
University of Illinois at Champagne-Urbana

b. Performing Organization: same

8. Type of Article: Theoretical

9. Abstract: In this theoretical paper, a sharp critique is made of the two main methods of evaluating flight training simulators--the transfer of training experiment and the pilot rating method--and an alternative method of evaluation, based on the success of predecessor devices and the laws derived from scientific research, is proposed.

Three principal flaws in the transfer of training method are identified. (1) The first is cost, in terms of simulator, parent aircraft, research staff, technicians, and subjects. The other two flaws pertain to the requirement that both experimental subjects and controls, by the time they transfer to the parent aircraft, must have sufficient proficiency to avoid accidents and generate meaningful performance measures. Because of this, (2) the controls do not present a no-practice baseline, and (3) the experimental subjects may only perform under the precondition of a positive outcome.

Eight major problems are identified in the pilot rating method of evaluating simulators: (1) The assumption that the amount of transfer of training is positively related to

A part-task simulator is defined as a training device for only critical and difficult portion of the flying task. It is noted that, in view of the inconclusive evidence to prove that critical part-task trainer, the Air Force policy was to avoid detailed segmentation of task into low-order elements.

Four examples of part-task trainers are adduced and design problems are discussed. The chief problem in design of a part-task simulator is how much to simulate: there is little evidence to guide judgements on what to include in a part- task simulator.

A considerable number of empirical transfer-of-training studies are cited in favor of the effectiveness of low or moderate rather than high fidelity in the areas of control response precision, visual stimulus noise, proprioceptive feedback, and control-display relations. In many of these studies, differences in subject performances during learning in the simulator were observed as result of varying fidelity; however, the performance differences quickly disappeared in the transfer environment.

It is important to note that these findings come from studies of tasks of a continuous psychomotor nature and that safe generalizations are limited to this class of activity. It was found, for example, that delay of feedback on the simulator impairs transfer to operational equipment where feedback is rapid (though transfer is not impaired in the reverse situation).

Simulation for proficiency measurement, however, appears to require higher fidelity than training simulation; furthermore, proficiency measurement simulators differ from training simulators in a need for higher reliability and for automatic scoring mechanisms, and the non-necessity of familiarization features often found in training simulators.

1. Author: Adams, Jack A.

2. Title: Some Considerations in the Design and Use of Dynamic Flight Simulators

3. Source: AFPTRC-TN-57-51, April 1957.

4. Topic Keywords: Flight simulation ; Fidelity ; Transfer of training ; Proficiency measurement ; Part-task ; Whole-task ; Low fidelity .

5. Short Summary: This review of issues and research in the design and use of flight simulators discusses the differences in requirements between whole-task and part-task simulators. It compares training and proficiency measurement simulators, and considers simulator fidelity in relation to both training requirements and proficiency measurement requirements. Evidence is cited to show effectiveness of low fidelity simulators in training tasks of a continuous psychomotor nature, whereas greater fidelity is necessary for proficiency measurement.

6. Devices: F-86D Flight Simulator; Radar Navigation Trainer; C-11C jet instrument trainer; T-33A (MF-1) Cockpit Procedural Trainer; SNJ Operational Flight Trainer; OSU Pilot Training Research Simulator

7. Institutions:

a. Sponsor: Air Force Personnel and Training Research Center, Lackland, AFB, TX 78236

b. Performing organization: Operator Laboratory, AFPTRC Air Research and Development Command, Randolph AFB, TX 78148

8. Type of Article: Review

9. Abstract: This review of issues and research in the design and use of flight simulators discusses the differences in requirements between whole-task and part-task simulators, and discusses simulation fidelity in relation to both training requirements and proficiency measurement requirements.

Advantages and disadvantages of whole-task simulators are discussed, and the criteria for effective simulation are applied to characteristics of a specific whole-task simulator, the F-86D, which at the time of this paper's publication was one of the more sophisticated trainers in use.

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Theoretical Articles

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on the average older and had spent more time in grade than the experimental group.

Subjects and controls took alternate forms of a 40-item multiple choice exam immediately before and after the course of instruction; they also took an oral, examiner-scored performance test within 5 days of the end of the course.

Multiple-regression analysis showed that OJT time prior to the course was a significant variable.

b. Results:

(1) Key Data:

OJT TIME	Performance Test Score MTU	SIM	Difference Between Groups
3 months or less	59.92	69.66	10.14 ($p < .10$)
3-6 months	79.25	74.55	4.70
6 months or more	92.09	89.18	2.91

(2) Verbal Description: No statistically significant difference was found in the performance of the simulator-trained and the MTU-trained groups related to training device. However, when the subjects and controls were subdivided into groups in respect to OJT time they had received prior to the course of instruction, a significant difference was found between the groups of less-experienced trainees (under 3 months OJT) on their performance test scores.

c. Authors' Conclusions: Instruction on the simulator was found at least equal to instruction on the MTU, and there is evidence favoring the benefits of the simulator training for trainees with less than 3 months OJT. Since the T-2 aircraft is comparatively simple, caution must be exercised in extending the results of this study to more complex aircraft systems.

multiple- choice
(2) Performance post-test, an examiner-scored oral exam

f. Experimental Setting/Training Context: Institutional, classroom and hands-on

g. Statistical Methods: Pooled variance "t" test; multiple linear regression

h. Variables Being Manipulated:
(1) Training Devices:
(a) EC II computerized multiple programmable maintenance simulator
(b) Maintenance Trainer Unit (actual equipment modified for training)
(2) Fidelity Levels:
(a) Physical: of simulator, not specified, apparently medium-low; of MTU, high
(b) Functional: of both devices, high
(3) Type of Task/Skill Required: part identification; troubleshooting; maintenance; cognitive; psychomotor; motor; perceptual; procedural
(4) Task Difficulty: Medium

i. Stage of Training: Skill, transition

j. Trainee Sophistication: varied, primarily intermediate

k. Incorporation of Device into P.O.I.: instructor-managed

l. User Acceptance or Attitude: not discussed

m. Use of Instructional Features: not specified

9. Abstract:

a. Study Synopsis: The study was designed to compare the effectiveness of a computerized, multiply-programmable maintenance training simulator, the EC II, with a conventional hardware trainer, the Maintenance Training Unit, or MTU, in the training of maintenance skills, within a relatively simple, one-week maximum course of instruction (the T-2C aircraft maintenance training program). The experimental, simulator-trained group consisted of 35, the control group of 87 naval maintenance personnel, having a fairly wide range of military maintenance experience. The control group trained on the MTU, was

1. Authors: Wright, Joanne, & Campbell, Jane

2. Title: Evaluation of the EC II Progammable Maintenance Simulator in T-2C Organizational Maintenance Training

3. Source: NADC-75083-40, May 1975

4. Topic Keywords: Maintenance-training-simulator ; Aircraft Maintenance ; Maintenance Troubleshooting .

5. Short Summary: A study evaluating the EC II computerized multiply-programmable simulator for maintenance training found it equally as effective as the standard Maintenance Training Unit which was a piece of actual equipment modified for training purposes. However, the simulator was more effective for trainees with less experience.

6. Devices:

a. EC II computerized multiply programmable maintenance simulator

b. Maintenance Training Unit (actual equipment modified for training)

7. Institutions:

a. Sponsor: Naval Air Systems Command, Washington, DC 20361

b. Performing Organization:
Naval Air Development Center, Warminster, PA 18974

8. Type of Article: Experiment

a. Number of Groups: 2

b. Description of Groups:
(1) Subjects: 35 naval maintenance personnel
(2) Controls: 87 same, but with average 2 years more time in grade than subjects
NOTE: Subjects and controls assigned from a pool with paygrade levels E-2 to E-7 and OJT experience range from less than 1 week to 2 years.

c. Tests or Trials/Timing: Pre-Test; Post-Test

d. Number of Different Types of Measures: 2

e. Description of Measurements and Ratings:
(1) Pre-test and Post-tests, written: 40-item

favoring the ASUPT- trained groups in:
(a) training time to criterion (see above);
(b) contact check ride scores (see above);
(c) grades in subsequent training block.

No significant differences were found between the ASUPT-trained subgroups with motion and without motion; however the small size of the sample dictates this results should be regarded with caution.

Questionnaire results showed the IP's in general favored the ASUPT greatly over the T-4.

c. Authors' Conclusions: The study has clearly shown that a sophisticated full mission flight simulator can be used to increase training effectiveness in the Air Force Undergraduate Flying Training Program. This test realized a reduction of one-quarter of the regularly scheduled flying training hours at a cost of only 2 simulator hours for each T-37 aircraft hours. Savings in instrument training has precedent, but the savings in basic contact training indicates an unexploited capability.

While sample sizes were too small for high confidence conclusions, there was no evidence in this study that platform motion in the simulator provided an increase in transfer of training.

(2) Features used: unspecified. For device capability, refer to AFHRL-TR-74-43, pp. 17-26

9. Abstract:

a. Study Synopsis: This study was designed to explore the utility of integrating the Advanced Simulator for Undergraduate Pilot Training with a new training syllabus, in place of the syllabus using the older instrument flight simulator T-4. This was the first effort to incorporate a full mission simulator into an operational pilot training program. Several problem areas were identified in the training program as well as in the device itself.

Eight undergraduate pilot training students were trained to specified levels of performance in all major areas of basic pilot training using the ASUPT; half were trained using the platform motion system and half without. Subsequently, they completed basic pilot training in T-37 aircraft. Training hours required and check ride scores were compiled for each subject. Similar data were collected for a control group of eight trainees using the conventional syllabus employing the T-4 instrument trainer. Outside of the device training, other aspects of the two courses in instruction, such as time in classroom, were roughly equivalent.

b. Results:

(1) Key Data:

Aircraft flying hours used by experimental & control groups to checkflight proficiency; group means

	Basic & Presolo	Advanced Contact	Instru- ments	Forma- tion	Navi- gation	* Total
ASUPT Group	14.2	18.7	9.0	13.7	7.1	70.7
Normal-Syllabus (T-4) Group	25.7	19.4	14.4	14.8	8.2	91.3
% hours saved	45	04	38	13	13	23
Training Effec- tiveness Ratio	0.60	0.11	0.52	1.00	0.24	0.48

* (Note: there were 6 other segments for which data were compiled to reach the total; those not shown here as no % saved or T.E.R. were computed)

Contact Check Rides: Experimental ASUPT Group, 90.85%, Control T-4 Group, 87.35%. $p<.01$

(2) Verbal Description: Significant and practically important differences were found

c. Tests or Trials/Timing: One post-test (checkflight); attitude questionnaire for IP's

d. Number of Different Types of Measures: 3

e. Description of Measurements and Ratings:
(1) Number of flying hours to reach criterion (OK for checkflight)
(2) Checkflight scores (IP graded)
(3) Subsequent performance in later training block

f. Experimental Setting/Training Context: Institutional, hands-on

g. Statistical Methods: not specified

h. Variables Being Manipulated:
(1) Training Devices:
(a) Advanced Simulator for Undergraduate Pilot Training, high fidelity visual and instrument flight simulator; with platform motion and without motion
(b) T-4 Instrument Trainer used in standard syllabus
(2) Fidelity Levels:
(a) Physical: of ASUPT, unspecified, presumably high of T-4, unspecified, presumably high
(b) Functional: of ASUPT, high of T-4, unspecified, presumably medium-high for instrument, none for visual
(3) Type of Task/Skill Required: Aircraft piloting; operations, cognitive, psychomotor, motor, perceptual, procedural, whole task (full-mission jet aircraft flight)
(4) Task Difficulty: high

i. Stage of Training: skill, transition

j. Trainee Sophistication: intermediate

k. Incorporation of Device into P.O.I.: instructor-managed

l. User Acceptance or Attitude:
(1) Instructors: very good as measured by questionnaire
(2) Students: good

m. Use of Instructional Features:

(1) Intensity: intensive

1. Authors: Woodruff, Robert R., Smith, James F., Fuller, John R., & Weyer, Douglas C.

2. Title: Full Mission Simulation in Undergraduate Pilot Training: An Exploratory Study

3. Source: AFHRL-TR-76-84, December 1976

4. Topic Keywords: Aircraft Flight Simulation ; Motion Simulation ; Visual Simulation ; Training Effectiveness ; Transfer of Training .

5. Short Summary: An exploratory study of the training effectiveness of the Advanced Simulator for Undergraduate Pilot Training. The study found that training on the device can reduce the trainees' actual aircraft flight requirements to achieve full mission proficiency, as compared with the conventional syllabus using the T-4 instrument trainer. There was no evidence that platform motion in the simulator produced any increase in transfer of training.

6. Devices:

a. Advanced Simulator for Undergraduate Pilot Training high fidelity instrument and visual flight trainer

b. T-4 instrument flight simulator

c. T-37 jet trainer (transfer environment)

7. Institutions:

a. Sponsor: HQ Air Force Human Resources Laboratory (AFSC), Brooks AFB, TX 78235

b. Performing Organization: Flying Training Division, AFHRL, Williams AFB, AZ 85224

8. Type of Article: Experiment

a. Number of Groups: 2

b. Description of Groups:
(1) Subjects: 8 Undergraduate Pilot Students with less than 50 hours flying experience (except that 1 had approximately 200 hours light plane experience; to be trained on ASUPT
(a) 4 with platform motion
(b) 4 without motion
(2) Controls: 8 same (all with less than 50 hours flight experiment)

performance decreased as the transfer practice continued.

Acceptance data from trainees before transfer and after training indicated a significant difference in preferences among the three devices. After testing, however, these differences disappeared. Instructors consistently rated the 17-4M better than the other two devices.

c. Authors' Conclusions: Detailed analysis indicated that the relative superiority of the 17-4M group in some aspects of transfer can most likely be attributed to the role of instructors, in enhancing training on a new--and as they saw it, improved--device. Several factors in addition to the device itself can determine what skill is acquired, how rapidly acquisition takes place, and what degree of transfer results. In the present study instructors appear to have played a central role in determining the rate of acquisition as well as the nature of the specific skills which were acquired.

The three devices employed in the BOT transfer of training study were quite similar in effectiveness. The real issue in evaluating these or any other devices lies in defining the training objective, both in terms of content and the level of proficiency required. In the stage of training under study, the emphasis among training personnel appeared to be on ensuring that trainees know how to apply BOT, and not on demonstration of a high level of proficiency. Given this objective, use of the 17-B4 for this purpose would seem unwarranted. The 17-B4 is clearly far more sophisticated than is necessary in this context.

9. Abstract:

a. Study Synopsis: This report reports on an experiment comparing the effectiveness of three Burst-on-Target (BOT) training devices for preparing Advanced Individual Training personnel to apply BOT techniques with the 3A102B laser device mounted in the M60A1 tank. The three devices were: (1) 17-4 "Green Hornet", a relatively simple Burst-on-Target simulator; (2) 17-4M, a version of the 17-4 modified for the study to improve versatility, instructional capability, and ease of handling the controls; (3) 17-B4, Conduct-of-Fire Trainer, a complex and more physically realistic device. Functional fidelity varied between the three, but not in a way systematic enough to place the three devices on a continuum.

Three groups of 18 trainees each were trained to a proficiency criterion on the devices. A fourth, control group, trained for a specified number of trials rather than to criterion; they were trained on the M3A102B device which was used for transfer testing of all subjects. Following training, all groups performed 80 trials on the M3A102B laser device--the transfer test. Accuracy (percentage of hits), speed (time between bursts) data, and number of trials to criterion were all recorded. In addition, device acceptance questionnaire data were obtained from both trainees and instructors.

b. Results: In the acquisition phase, the mean of the number of trials required to reach the criterion (90% hits on second shot of the BOT series) varied significantly between groups. The means were 125.0 for the 17.4 group, 169.4 for the 17.4M group, and 134.1 for the 17.4B group.

Speed data during transfer testing showed significant superiority of training groups over the control group at each of the initial four blocks of trials, which disappeared thereafter. It appeared that the fact of having had prior training was more important than was the nature of the specific device on which practice occurred. However, the accuracy data indicated that prior training in applying BOT did not have a pronounced effect on BOT accuracy during transfer.

A second set of effects showed that, among the simulator-trained groups, the trainees who had practiced on the 17.B4 device showed no significant improvement in speed during transfer, while those trained on the other two devices did. The spread in

(2) 18 same
(3) 18 same
(4) Controls: 18 same

c. Tests or Trials/Timing: In-process trials; post-test (transfer task)

d. Number of Different Types of Measures: 3

e. Description of Measurements and Ratings:
(1) Percent hits (accuracy)
(2) Time between bursts (speed)
(3) Trials to criterion--in-process trials only

f. Experimental Setting/Training Context: Institutional, hands-on

g. Statistical Methods: ANOVA; Scheffe tests; Vincent curves

h. Variables Being Manipulated:
(1) Training Devices: as above, section 6
(2) Fidelity Levels:

	17-4	17-4M	17-B4
Physical	Medium-low	Medium-low	Medium-high
Functional	Medium	Medium	Medium

(3) Type of Task/Skill Required: operations, psychomotor, perceptual, part-task
(4) Task Difficulty: Medium-low

i. Stage of Training: introduction, familiarization, skill

j. Trainee Sophistication: novice

k. Incorporation of Device into P.O.I.: lock-step

l. User Acceptance or Attitude:
(1) Instructors: more favorable for the 17-4M device
(2) Students: more favorable for the 17-4M device prior to transfer; afterwards, roughly equal for all devices

m. Use of Instructional Features:
(1) Intensity: assumed intensive
(2) Features used: not specified

the rated similarity between simulator and aircraft is only a partial truth, as numerous experiments demonstrating the effectiveness of low fidelity trainers have indicated. (2) There is evidence that pilot ratings, which are subjective and individual, can reflect pilot experience level as much or more than adequacy of simulation. (3) Experience in the simulator can make the simulator rather than the aircraft the frame of reference. (4) Dimensions of the simulator interact and may not always be distinguished by the pilot. (5) The pilot cannot always tell where the poor source of simulation originates, nor what deficiencies might be due to his own lack of skill, as distinct from deficiencies of the device. (6) There is not always a positive correlation between ratings and flying performance. (7) Simulator effectiveness cannot be separated from the influence of the instructor and the effectiveness of the training syllabus. (8) Most fundamentally, the flight simulator cannot be regarded as an "earthbound aircraft"; rather, it is a teaching device, and must be judged on its merits as a trainer, not on its faithfulness of mimicry.

With a view to formulating a new basis for flight simulator evaluation, five major psychological principles are prepounded: (1) the dependence of human learning on knowledge of results; (2) that the key to piloting is perceptual learning, which is an increase in the ability to extract information from stimulus patterns as a result of experience; (3) stimulus-response learning is highly useful; (4) transfer of training is highest when similarity of the training and transfer situations is the highest; (5) a trainee must be motivated, and the task itself supplies some of the motivation.

The author states that "the reason for putting forth these principles is the assertion that a system built on sound scientific laws needs less concern with evaluation because a good scientific law produces accurate prediction, and when the outcome can be predicted it is redundant to conduct an evaluation," and concludes that there is a "possibility that system testing can be set aside when the scientific laws are known to be strong and when predecessors, based on the same laws, have been successful."

1. Authors:
Advisory Group for Aerospace Research and Development: Osterveld, Will J., Key, David L., Bates, George P. Jr., Bray, Richard, Chambers, Walter S., Friedrich, Heinz, Gainer, Charles A., Hammer, Niels-Peter, Koevermans, Kim, Rolfe, John M., Schultz-Helbach, Smith, James F., Staples, Ken, & Young, Laurence R.

2. Title: Fidelity of Simulation for Pilot Training

3. Source: AGARD-AR-159 Working Group 10, December 1980, NTIS AD-096 825

4. Topic Keywords: Flight simulation ; Low fidelity ; Fidelity of simulation ; Perceptual fidelity ; Platform motion ; Training effectiveness .

5. Short Summary: A study of fidelity of simulation for pilot training covers a wide range of topics relating to fidelity. It points out the shortcomings of using fidelity alone as a criterion for simulator design, and recommends avenues of research to study and define the relationship of fidelity to training effectiveness.

6. Devices: not applicable

7. Institutions:

a. Sponsor: Advisory Group for Aerospace Research and Development, 7 Rue Ancelle, 9220 Nevilly-sur-Seine, France

b. Performing Organization: same

8. Type of Article: Review

9. Abstract: The AGARD "Working Group 10" comprised engineers, psychologists, and physiologists from the U.S., Great Britain, Germany, and The Netherlands. In this report, the team attempted to "1. Outline a framework for the logical selection of training simulator facilities with guidance for making the various trade-offs. 2. Address the question of how much fidelity is required to train a given flight phase in isolation."

In the first section of this report, the general term fidelity is separated into two dimensions: (1) Objective Fidelity "provides an engineering viewpoint and is the degree to which a simulator would be observed to reproduce its real- life counterpart aircraft in flight, if its form, substance and behavior were sensed and recorded by a nonphysiological instrumentation system ....." (2)

Perceptual Fidelity "provides a psychological/physiological viewpoint and is the degree to which the trainee subjectively perceives the simulator to reproduce its real-life counterpart ....."

These definitions serve to distinguish between the real cues measured objectively and what the pilot experiences subjectively. This distinction implies one important justification for reducing engineering, i.e., "objective" fidelity in the simulator, since less than 100% objective fidelity can still produce 100% perceptual fidelity. Unfortunately, "the knowledge of human physiology is insufficient to determine how much objective fidelity is required to achieve a given level of perceptual fidelity."

It is around this last dilemma that the bulk of this report pivots. The following sections of the report present (1) the training specialists' viewpoint on fidelity of simulation; (2) an overview of pilot cuing mechanisms, focussing on visual, vestibular, and kinetic motion cues; (3) the simulator technologists' assessments of existing motion, visual, and computer model technology; and (4) the Working Group's overall conclusions and recommendations. Appendices provide a description and evaluation of methods of assessing training effectiveness (including the Simulator Fidelity Model); physical characteristics of existing facilities; a survey of pilot opinions of existing simulator facilities; a detailed review of the technology of visual systems.

Major findings and conclusions of the Working Group were as follows:

a. Fidelity:

(1) Specific cues should be simulated only if essential to accomplishing the training objective; this necessitates a clear statement of the training objective.

(2) Visual cuing is more important to transfer than motion cuing, given current technology.

(3) Simple devices can be very effective in early stages of learning, particularly in learning procedural tasks.

(4) Reducing the level of complexity in the simulator can often improve training effectiveness by enabling the student to concentrate on those elements relevant to the task being trained.

(5) Emphasis should be on achieving perceptual fidelity rather than objective fidelity.

(6) "The state of knowledge of sensory information is not sufficient to completely define the needs for simulation. Some of the material... may exist in the perception literature in forms which could be made useful to the simulator community."

(7) Further research is required "to define how cuing fidelity impacts on training effectiveness for a matrix of aircraft, tasks, pilot experience, and instruction techniques."

(8) One approach to evaluating the effectiveness of lower fidelity would be to reduce the cuing fidelity of existing devices that do train well, and measure the effects, rather than to proceed in the opposite direction of adding fidelity to simple devices.

b. Instructional Methods:

(1) The most effective simulator training allows the student to use as much time as he needs to meet a criterion standard of performance, rather than using a fixed amount of time.

(2) Since students tend to reflect instructor attitudes, the instructor should be led to realize and espouse the usefulness of the device.

(3) Experienced trainees are strongly motivated by competition or a comparative measure of probability of success.

c. Assessment of Training Effectiveness - is best accomplished through the transfer of training model. "...Equating training effectiveness with fidelity is a coverup for our ignorance about transfer and leads to the development of possibly unnecessarily costing devices."

1. Authors: Baer, Donald K., Jones, D. W., & Francis, Christopher C.

2. Title: Nuclear Power Plant Simulators: Their Use in Operator Training and Requalification

3. Source: National Technical Information Service NUREG/CR- 1482, July 1980

4. Topic Keywords: Nuclear Power Plant Simulation ; Comprehensive Risk Assessment ; Simulated Malfunction .

5. Short Summary: A study of simulator training programs for nuclear power plant operators in the U.S. recommended ways to improve the training programs, principally through developing a method to identify what malfunctions are important to simulate.

6. Devices: PWR and BWR Nuclear Power Plant Simulators

7. Institutions:

a. Sponsor: Nuclear Regulatory Commission, Washington, DC

b. Performing Organization: Oak Ridge National Laboratory, TN 37830

8. Type of Article: Survey

9. Abstract: In the wake of the 1979 accident at Three Mile Island, the Nuclear Regulatory Commission ordered a survey of the capability of U.S. nuclear power plant simulators and their associated operator training programs. This study conducted by the Center for Nuclear Studies at Memphis State University used NRC records, Simulator Bid Specifications, simulator development studies, simulator training staff interviews, site visits, plant specifications, licensee event reports (LERs), and nonnuclear simulator data, as evidence for this report. A capsule review of the TMI-2 accident is included in the report to illustrate the complexity of events for which operators should be prepared. The subsequent sections of the report deal with (1) existing nuclear power plant simulator capabilities; (2) simulator training programs; (3) proposed procedures for selecting equipment malfunctions for simulation.

With regard to existing simulator capabilities, the study concluded that in general "the simulator hardware and software are not the limiting factors to more effective training... rather, it is the utilization of simulators in

training programs...that (could) be substantially improved." It was noted, however, that mathematical models of two phase coolant flow (i.e., water plus steam) in a PWR system were still inadequate to thoroughly simulate an accident condition such as transpired at Three Mile Island.

In view of the general satisfactoriness of the simulators themselves, the study focussed on the training programs and objectives. Two principal issues were noted:

(1) The NRC "had not had a well-defined regulatory framework for design qualifications or review of simulators or their use in operator training," and the nuclear industry had "not made use of task analyses or a comparable formal methodology" for designing operator training programs, so that "decisions tend(ed) to be made on... a subjective basis." The study recommends the use of a systematic task-analytic training methodology, and a strengthening of NRC regulation of training. A comparison was made with U.S. Air Froce pilot training programs in which training objectives and specific performance criteria are explicitly spelled out.

(2) A comprehensive risk assessment of accident sequences for nuclear power plants had not been performed. Since a limited amount of time can be spent training an operator to respond to abnormal events, the events to be simulated must be selected to reflect the probability and the criticality (in terms of safety and dollars costs) of such events. The final section of this report develops and demonstrates procedures for selecting equipment malfunctions for simulation, by ranking events on a point system in terms of (a) safety, (b) frequency, (c) potential for subsequent malfunction, and (d) significant plant outage. A list of malfunctions devived from a study of 3,000 LERs recorded in a 6- month period in 1978 is appended.

1. Authors: Bailey, Jon S., & Hughes, Ronald G.

2. Title: Applied Behavior Analysis in Flying Training Research

3. Source: AFHRL-TR-79-38, January 1980

4. Topic Keywords: Flight Simulation ; Behavioral Analysis ; Task Analysis .

5. Short Summary: This paper lays out a basic framework of a behavioral analysis approach to simulation training, and suggests ways that the principles of behavior might be applied to simulated flying training.

6. Devices: not applicable

7. Institutions:

a. Sponsor: HQ Air Force Human Resources Laboratory (AFSC), Brooks AFB, TX 78235

b. Performing organization: Flying Training Division, Air Force Human Resources Laboratory, Williams AFB, AZ 85224

8. Type of Article: Theoretical

9. Abstract: Flight simulators have traditionally been designed around "the model of an instructor pilot who feels most comfortable teaching in an actual plane." However, the simulator has potential for training which is not possible in the actual plane. The purpose of this paper is to elucidate scientific principles of behavior and hypothetically to apply them to the analysis of flying tasks and to the design and use of flight training simulators.

The following basic principles of behavior are described and illustrated: Positive Reinforcement, Punishment, Shaping and Chaining, Prompting and Fading, Discrimination and Stimulus Control, and Generalization.

The chief disadvantages of training in a real airplane stem from the safety requirement: "The IP (must) put proper maneuvering above analyzing the instructional (or learning) process..." Also, "since the cockpit is operational and the instruments require constant monitoring... the student may easily be overloaded with information in the early stages of instruction and be unable to progress... systematically. No opportunity to practice a particular part of a maneuver is feasible..." In other words, the lack of "realism" in a simulator in these respects constitute a potential advantage

in training. However, until recently these advantages have not been realized because "psychologists specializing in the learning process have not been involved in the design phase of simulator development."

A new mode for simulator design is proposed which begins with a behavioral/task analysis. This analysis can be done in one or more of four dimensions: component analysis, chain or sequence analysis, dimension of difficulty analysis, and augmented feedback analysis.

The model, based on analysis of tasks and using behavioral principles, is applied hypothetically to the example of learning how to land an aircraft. This example employs the principles of backwards chaining, cognitive pretraining, graduated difficulty, and criterion-based individualization of training.

The paper concludes with a recitation of a number of fundamental questions, as yet unanswered by research, related to the training features and effectiveness of simulators.

1. Author: Battelle Human Affairs Research Centers

2. Title: Simulator Fidelity and Training Effectiveness: A Bibliography with An Annotated Bibliography of Selected Documents

3. Source: Battelle Human Affairs Research Centers, December 1982, Safety Technology Program, Project T-2

4. Topic Keywords: Simulator Fidelity ; Training Effectiveness ; Flight Operations Training ; Nuclear Operations Training ; Maintenance Training .

5. Short Summary: An annotated bibliography provides 35 annotated references and a nonannotated bibliography provides 216 references (including citations of the annotated references) relating to simulator fidelity and training effectiveness.

6. Devices:

   a. Procedural Task Trainers

   b. Nuclear Power Plant Operations Simulator

   c. Flight Simulators

   d. Process Simulators

7. Institutions:

   a. Sponsor: Nuclear Regulatory Commission

   b. Performing Organization: Battelle Human Affairs Research Centers, 4000 N.E. 41st Street, Seattle, WA 98105

8. Type of Article: Review (bibliography)

9. Abstract: This bibliography is divided into two sections: Section A contains references to 35 articles and reports with annotations constructed in a uniform outline format; Section B cites 215 documents including those cited in Section A, without annotation. The subject matter of references in Section A relates to "issues of the psychological aspects of simulator fidelity and the effectiveness of training simulators." The subject matter of references in Section B related to "the role of simulators in operator training." Since the bibliography was prepared as part of a program for the Nuclear Regulatory Commission, there is more emphasis on issues pertinent to nuclear power plant operator training than would be found in a more

general-interest bibliography.

Annotated bibliographies cite author, title, source, and date of the reference, and are outlined as follows:

I. General Summary of Document
   A. Focal Industry
   B. Type of Document
   C. Basic Objective(s)
   D. Major Findings or Recommendations
II. Simulator Topic Focus
   A. Uses of Simulator Addressed
   B. Types of Simulators Addressed
III. Simulator Fidelity
   A. Fidelity Dimensions and Definitions
   B. Explicit Statement of Required Fidelity Level
   C. Variables Affecting Required Fidelity Level
   D. Criteria for Determining Required Fidelity Level
   E. Methods for Determining Required Fidelity Level
IV. Simulators in Training Systems
   A. Relationship to Training for Specified Tasks
   B. Relationship to Training Effectiveness
   C. Methods for Establishing Training Effectiveness
   D. Simulators as Part of Training Systems

A rough breakdown of the annotated section by subject content is as follows: Flight Operations Training, 9 documents (2 are empirical studies); Nuclear Reactor Operations Training, 5 documents (none are empirical studies); Other Operations Training, 5 documents (2 are empirical studies); Maintenance Training, 3 documents (none are empirical); General and Miscellaneous, 13 documents.

1. Authors: Baum, David R., Clark, Chriss, Coleman, T. Patrick, Lorence, Steve, Persons, Warren, & Miller, Gary

2. Title: Maintenance Training System: 6883 Converter/Flight Control Test Station

3. Source: Technical Report, AFHRL-TR-78-87

4. Topic Keywords: Simulation ; Maintenance Training ; Transfer of Training ; Fidelity .

5. Short Summary: The design features and operation of a maintenance training system (the 6883 Converter/Flight Control Test Station) are described. The description includes system capabilities for obtaining data on various dimensions of device utilization and training methodology. The simulator is discussed both as a prototype trainer and a research tool.

6. Device: 6883 Converter/Flight Control Test Station, a dual- computer interactive training device

7. Institutions:

a. Sponsor: HQ Air Force Human Resources Laboratory (AFSC), Brooks AFB, TX 78235

b. Performing Organization: Honeywell Systems and Research Center, 2600 Ridgway Parkway, Minneapolis, MN 55413

8. Type of Article: Conceptual/Methodological

9. Abstract:

a. Study Synopsis: This paper describes the design features and operation of a dual-computer driven maintenance training system (6883 MTS), including system architecture, hardware and software, instructor functions and procedures, and student interaction. It includes a hypothetical troubleshooting task learning scenario involving the interactions between instructor, student, and computer. This report also discusses use of the trainer to explore research issues in three areas: (1) transfer of training, (2) training techniques, and (3) automated performance/proficiency measurement.

Prior to development of the 6883 MTS, I-level Air Force maintenance training had been conducted on actual equipment. The following shortcomings of actual

equipment use in training were cited: (1) cost, (2) inflexibility to train for part-tasks, (3) low reliability, (4) high risk of severe injury to trainees, (5) high risk of damage to equipment through student error, (6) feedback requires instructor's continued presence.

Psychological rather than engineering fidelity was the key to developing a training system where the student performs (simulated) maintenance tasks monitored in an automated closed loop.

A number of trade-offs were made in the design of the MTS. To ensure cost-effectiveness, a philosophy of training by representative example was adopted. Frequently cost reductions could be achieved by using the same functionally simulated hardware to train a variety of different procedures. Concentration of simulated hardware in a single location reduced mechanical assembly costs. For example, each bay of the actual test station has an over temperature indicator that is tested during turn-on procedures. Because this test procedure is the same for all four indicators, only one of the four indicators is functionally simulated though all four indicators are represented visually.

b. Authors' Conclusions: There are at least three general areas of technical training research that can be addressed using the 6883 MTS: (1) transfer of training, (2) advanced training techniques, and (3) automated performance/proficiency measurements. The 6883 MTS provides a tool for collecting appropriate data on the question of transfer of training; measures obtained on this system could help achieve an acceptable level of objectivity, reliability, and validity in proficiency measurement. The 6883 MTS provides a test bed for evaluating the training utility of freeze, playback, and other techniques. It also provides a research tool for evaluating the relevance of its many possible recorded performance measures to practical proficiency and skill level.

1. Authors: Baum, David. R., Smith, Deborah A., Klein, Gary A., Hirshfeld, Stephen F., Swezey, Robert W., & Hays, Robert T.

2. Title: Specification of Training Simulator Fidelity: A Research Plan

3. Source: U.S. Army Research Institute for the Behavioral and Social Sciences Technical Report 558, February 1982

4. Topic Keywords: Fidelity ; Fidelity Specification ; Fidelity Guidance ; Maintenance Training ; Simulation .

5. Short Summary: This study provides (1) a theoretical review and discussion of issues pertaining to the relationship between simulator fidelity and training effectiveness; (2) a framework for fidelity research in maintenance training; and (3) specific experimental pilot study designs to investigate the impact of varying levels of fidelity on training.

6. Devices: None

7. Institutions:

a. Sponsor: U.S. Army Research Institute for the Behavioral and Social Sciences (PERI-IE), 5001 Eisenhower Avenue, Alexandria, VA 22333

b. Performing Organization: Honeywell Systems and Research Center, 2600 Ridgway Parkway, Minneapolis, MN 55413

8. Type of Article: Methodological

9. Abstract: This interim report provides the theoretical basis and design plans for empirical research on the relationship between simulator fidelity and training effectiveness. (The actual conduct of one of the proposed experiments and its results are presented in a subsequent, final report). The paper is divided into three principal sections: (1) Introduction and Background; (2) A Framework for Fidelity Research in Maintenance Training; and (3) Pilot Study Design Considerations and Paradigms.

a. Introduction and Background. A review of the literature, site visits and interviews with concerned agencies, and a fidelity research issues workshop, yielded the following list of issues in simulator training: (1) Fidelity--its definition, its implications in transfer of training, its dependence on

actual equipment characteristics, its sensitivity to the training environment, and its place in the context of task variables such as task type, task difficulty, task criticality, etc.; (2) Utilization--the incorporation of the simulator into the training program and its acceptance by users; and (3) Measurement (of training effectiveness--whether by transfer-of-training, by ratings of experts, or by reference to analytic models of learning.

b. A Framework for Fidelity Research in Maintenance Training. The framework is to be structured by the distinction between physical and functional aspects of fidelity proposed by Hays (1980), which suggests the following design:

		PHYSICAL SIMILARITY		
		Low	Medium	High
FUNCTIONAL SIMILARITY	Low	X	X	X
	Medium	X	X	X
	High	X	X	X

Three groups of maintenance tasks are identified: (1) Procedural; (2) Perceptual-Motor; and (3) Cognitive--based on the emphasis which these dimensions receive in the task. Of the three, Procedural Maintenance tasks were eliminated from further investigation in this study because it was felt that adequate research had already been done to show convincingly that high training simulator fidelity was not a requirement in teaching this type of task.

c. Pilot Study Design Considerations and Paradigms. General design considerations were (1) criteria of tasks to be learned; (2) manipulation of fidelity; and (3) transfer of training paradigm.

The task selected for investigation of the perceptual-motor maintenance task group was the truing of a bicycle wheel, a task easily studied in a laboratory, in which the required performance was felt to be representative of Army maintenance tasks. Six different studies were proposed for this task.

The task proposed for investigation of the cognitive maintenance task group was the playing of the card-game of bridge, selected because it is a decision task that can be analyzed into elements. A paradigm for analysis

would be drawn from information theory and a completed study of goal networks of proficient CPR paramedics.

1. Authors: Beck, Isabel, & Monroe, Bruce

2. Title: Some Dimensions of Simulation

3. Source: INSGROUP, Inc., February 1969

4. Topic Keywords: Simulation Games ; Simulator Fidelity

5. Short Summary: This theoretical paper summarizes some broad aspects of simulation, with emphasis on simulation games, in the context of education in general.

6. Devices: not applicable (a theory paper)

7. Institutions:

   a. Sponsor: INSGROUP, INC. (Instructional Systems Group), 640 Sea Breeze Drive, Seal Beach, CA 90740

   b. Performing Organization: Same

8. Type of Article: Theoretical

9. Abstract: This paper summarizes some broad aspects of simulation, principally of simulation games, in the context of education in general. Definitions and characteristics of simulation are given, with the four principal characteristics of simulation identified as follows:

   (1) Starts with an analogous situation
   (2) Provides for low risk input
   (3) Feeds back consequences symbolically
   (4) Is replicable

These characteristics are used to help make distinctions between role playing, games, and simulation. The dimensions of simulation discussed are:

   (1) The reality/fidelity dimension. Two aspects are mentioned: physical and time fidelity
   (2) The manipulation of complexity of decisions
   (3) Curriculum content aspects
   (4) The source or originator of the model on which the simulation is based
   (5) Replicability of the simulation for the same player or for subsequent players
   (6) Evaluation or measurement of performance

   Counter-based simulation games are discussed separately.

The authors point out that in simulation game instruction, the learning of process, particularly decision-making, far out weighs the learning of content.

Advantages and disadvantages of learning through simulation are listed. Advantages of simulation over direct experience in the operational environment are: cost, control over time (either to compress or to expand from real-world time), and ability to experiment. Disadvantages cited include design problems, chiefly in fidelity.

1. Authors: Blaiwes, Arthur S., & Regan, James J.

2. Title: An Integrated Approach to the Study of Learning, Retention, and Transfer - a Key Issue in Training Device Research and Development

3. Source: NAVTRADEVCEN Technical Report IH-178, August 1970

4. Topic Keywords: Transfer of Training ; Retention of Learning .

5. Short Summary: Issues which play significant roles in research into Learning, Retention, and Transfer are identified and applied to the characterization of 181 reports in the transfer of training literature.

6. Devices: not applicable

7. Institutions:

   a. Sponsor: Naval Training Device Center, Orlando, FL

   b. Performing Organization: Human Factors Laboratory, Naval Training Device Center, Orlando, FL

8. Type of Article: Review/Theoretical

9. Abstract: This paper attempts to identify distinct and meaningful issues which characterize research into learning, retention, and transfer, and then to categorize 181 reports according to these characteristic issues. Relationships between learning, retention, and transfer are briefly discussed, and three representative experiments are summarized, and four major features of a research program are presented.

Four general issues are identified which characterize Learning, Retention, and Transfer research:
(1) which subtasks, fund operationally, should be included in the training simulation;
(2) those variations in stimulus and response characteristics of the training system which should be incorporated;
(3) which instructional devices, materials, and methods should be introduced to improve learning and transfer;
(4) how much generalization should be built into training devices."

In addition to these issues, the 181 reports are characterized according to "whether they pertain to the topic of learning, retention and/or transfer; whether the

tasks... could be described as verbal, motor, perceptual, signal monitoring, complex, or procedural; and whether and what kind of other independent variables were manipulated."

A summary is given of trends in the literature which emerged in the course of this analysis, pertaining especially to the transfer relationship (i.e., what methods, materials and devices enhance transfe).

The discussion of the relationships between learning, retention and transfer focusses on the specificity of the transfer issue. Theories are mentioned which suggest the importance of general or nonspecific factors in learning, and the importance of extra-experimental learning in the transfer of training context.

The authors also identify four major concerns of their research program:

(1) providing rich and diverse experimental situations with which to examine the rules of transfer;
(2) evaluating the effects of the length of the transfer test;
(3) evaluating the effects of the difficulty of the training task;
(4) evaluating the effects of variations in the training objectives.

One experiment concerned with the task difficulty issue, and two experiments concerned with the fidelity issue, were briefly summarized.

1. Author: Brock, John F.

2. Title: Maintenance Training and Simulation: Design Process and Evaluation Criteria

3. Source: Proceedings of the Human Factors Society 22nd Annual Meeting, Detroit, MI, October 16-19, 1978, 260-266

4. Topic Keywords: Maintenance Training Simulation ; Maintenance Troubleshooting ; Cost-Effectiveness ; Performance Evaluation .

5. Short Summary: Different types of maintenance tasks and methods of training via simulation are identified. A review of evaluative practices suggests some changes to more accurately reflect the cost of training systems to the user and an adaptive model of instructioal system evaluation is proposed.

6. Devices:

   a. Hagan Automatic Boiler Control System

   b. Bessler Cue - See audiovisual

7. Institutions:

   a. Sponsor: Navy Personnel Research and Development Center, San Diego, CA 92152

   b. Performing Organization: same

8. Type of article: Conceptual

9. Abstract: This paper endeavors to identify maintenance training categories and training simulation system characteristics, and to critique methods of evaluaing maintenance training systems, and makes suggestions for imporvements in system analysis and evaluation.

Three kinds of maintenance task categories are identified:
(1) Procedural, which includes Preventive Maintenance, Systems Checkout, and General Inspection,
(2) Psychomotor, which includes Calibration, Alignment, and Repair,
(3) Schema, which includes Fault Detection and Troubleshooting.

Although analyses of procedural tasks have been heavily documented, analyses of the more complex psychomotor tasks have been less satisfactory. Most difficult to analyze have been schema tasks--fault detection and troubleshooting.

Attempts to link schema theory with performance have been futile. "...The development of analytic techniques to discover the schema of maintenance technicians is critical and, with the help of artificial intelligence systems, has a high probability of success."

Even where task analyses are precise, and lead to identifiable learning objectives, the problems of meeting learning objectives remain complex and their solutions rely to a great extent on intuition.

The advantages of simulation in maintenance training are summarized briefly as: Cost, Reliability, Modifiability, Hands-on Opportunities, Safety, Evaluation of Student Performance as Good or Better.

Instructional systems available to the maintenance training designer are identified as follows: Actual Equipment, Mock-Up, 3-Dimensional-2-Dimensional Mix, 3-D Schematic, 2-D/Image Interface, 2-D/Keyboard Interface, and Projected Displays. The problem lies not in available techniques, but in "determining what skills must be taught."

The measurement of system effectiveness by tests at the end of the training period do not adquately reflect the true effectiveness of the training in the total service context; it is necessary to evaluate training by measuring field performances of course graduates, via records of system downtimes, mean times to repair, field supervisor ratings, and so on. "Until the operational community can provide the training community with evidence that a particular way of training is improving the way systems work, training design people will continue to rely on schoolhouse measures exclusively."

Likewise, cost analyses which only measure cost at the schoolhouse level, and not the impact of training in the field, fail to evaluate the totality of costs to the military service which is the ultimate training system user. Cost differentials realized in the field through more efficient performance of equipment and reduced down-time as a result of training are just as important as Transfer Effectiveness Ratios.

1. Author: Caro, Paul W.

2. Title: Aircraft Simulators and Pilot Training

3. Source: Human Factors , 1973, 15(6), 502-509

4. Topic Keywords: Flight Simulation ; Functional Context Training ; Transfer of Training .

5. Short Summary: A review of the role of simulators in pilot training stresses training techniques over physical simularity of the training device to the aircraft as the critical factor in determining training effectiveness.

6. Devices: GAT-2 instrument trainer; Cockpit mockup; 1-CA-1 Trainer; 2-B-24 Simulator

7. Institutions:

a. Sponsor: Human Resources Research Organization , Fort Rucker, AL 36362

b. Performing Organization: same

8. Type of Article: Theoretical/Review

9. Abstract: The thesis of this paper is that "a proper training program can compensate for lack of physical similarity between the training device and the aircraft, but a realistic simulator is a poor substitute for competent training.... The key is the program, not the hardware."

In support of this contention, specific techniques for optimizing the effectiveness of training--using either simulators or less sophisticated training devices--are described, and several experiments are cited in which devices as crude as "a cockpit mockup made of plywood and photographs by unskilled labor...at a cost of about $30" produced substantial transfer of training. The techniques which are described are summarized as follows:

a. Functional context training:
b. Individualization of training;
c. Sequencing of instruction;
d. Minimizing over-training;
e. Efficient utilization of personnel
f. Use of incentive rewards
g. Crew training
h. Peer training
i. Minimizing equipment costs
j. Objective performance measurement

The author maintains that these techniques are based on an

"orientation that training is a technology which can be engaged in, after appropriate training, by reasonably bright and adaptable people, not an art which is an inherent characteristic of the 'good instructor.'"

The motivation and training of instructors are stressed. The attitude of an instructor is usually reflected by the student; design and management of the training program should take this into consideration by employing techniques such as the use of incentive rewards cited above.

1. Author: Caro, Paul W.

2. Title: Some Factors Influencing Air Force Simulator Training Effectiveness

3. Source: HumRRO-TR-77-2, March 1977

4. Topic Keywords: Flight simulation ; Platform motion ; Simulation fidelity ; Training effectiveness .

5. Short Summary: A study of ten current U.S. Air Force simulator training programs identified factors influencing effectiveness, but discovered that no quantitative evaluation had been done which would assess the relative impact of these factors.

6. Devices:

a. FB-111 Aircraft Simulator

b. C-5 and C-5A Simulators

c. F-106 Simulator

d. A-7D Simulator

e. GAT-2

f. Advanced Simulator for Pilot Training

7. Institutions:

a. Sponsor: Air Force Office of Scientific Research (NL), Bolling AFB, DC 20332

b. Performing organization: Human Resources Research Organization, 300 North Washington Street, Alexandria, VA 22314

8. Type of Article: Review

9. Abstract: The study described in this report was undertaken to identify the principal factors that influence the effectiveness of Air Force simulator training programs. The report is divided, after the introduction, into three main sections:

a. Methods Used to Determine Simulator Effectiveness. This section discusses characteristics and applications of ten different investigative models:
(1) Transfer of Training Model
(2) Self-Control Transfer Model

(3) Pre-existing Control Model
(4) Uncontrolled Transfer Model
(5) Simulator-to-Simulator Transfer Model
(6) Backward Transfer Model
(7) Simulator Performance Improvement Model
(8) Simulator Fidelity Model
(9) Simulator Training Program Analysis Model
(10) Opinion Survey Model

b. Principal Factors Influencing Simulator Training Effectiveness. This section discusses the following factors derived both from the survey and from a literature search:

(1) Simulator Design
(2) Design for Training
(3) Visual Fidelity
(4) Motion Fidelity
(5) Handling Characteristics
(6) Training Programs
(7) Personnel
(8) Instructors
(9) Attitudes
(10) Expectations
(11) Miscellaneous

c. Recommendations. Recommendations address most of the factors listed above.

Regarding methods used to determine simulator effectiveness, "a general absence of formal (i.e., objective, quantitative) evidence of the value of the simulator training activities surveyed" was found, although most personnel surveyed believed strongly in the cost-effectiveness of their simulation training programs. Of the ten programs surveyed, none had used the Transfer of Training Model to evaluate program effectiveness. The author comments that "it may be that simulator training has become too well accepted by the Air Force."

In the discussion of principal factors influencing training effectivenss, a great deal of attention is placed on device design fidelity. It is noted that inclusion of instructional features such as freeze, playback, etc., which are believed to enhance the teaching function, lowers the fidelity of the training equipment. The capability of the device to train legitimately out-weighs considerations of fidelity per se. With this in mind, it is suggested, for example, in connection with visual fidelity, that "it sometimes appears that unnecessary emphasis is placed upon designing visual displays that look like the "real

world" viewed through the aircraft's wind screen.... It is likely that the display design requirements are more responsive to fidelity goals than to training necessities." A practical obstacle to sacrificing fidelity in the interest of cost-effectiveness is the opposition of instructors who insist on the importance of realism of aircraft "feel" in the simulator, even when, as in the case of simulated motion, the contribution of the simulation to training appears weak when measured experimentally.

Recommendations focus on the need for emphasizing validation of simulator training programs objectively, and researching simulator design characteristics in relation to training objectives in a systematic way. "Design concepts should be sought that will emphasize the simulator's training purposes rather than the characteristics of the aircraft being simulated."

Overall, it was noted that both literature and personnel surveyed failed to agree on simulator design specifics in many areas. "An obvious conclusion to be drawn from the present study is that too little attention has been paid to date to the effectiveness of simulator training."

1. Authors: Eddowes, Edward E., & Waag, Wayne L.

2. Title: The Use of Simulators for Training In-Flight and Emergency Procedures

3. Source: NATO Advisory Group for Aerospace Research and Development AGARDograph No. 248, June 1980

4. Topic Keywords: Flight Simulation ; Emergency Flight Procedures ; Measurement Content Validity ; Measurement Empirical Validity ; Performance Measurement .

5. Short Summary: This report examines the role of flight simulators in training with a focus on a few key issues, reviews a number of empirical studies, and discusses in detail the problem of performance measurement.

6. Devices:

a. Advanced Simulator for Pilot Training (ASPT)

b. C-5A Operational Flight Simulator (OFS)

c. Ch-47 Operational Flight Simulator

d. Device 2F87f Operational Flight Trainer

e. SNJ Link Trainer

f. 1-CA-2 SNJ Link Trainer

7. Institutions:

a. Sponsor:
NATO Advisory Group for Aerospace Research and Development, 7 Rue Ancelle, 9220 Neuilly-sur-Seine, France

b. Performing Organization: Williams AFB, AZ 85224, Air Force Human Resources Laboratory

8. Type of Article: Review

9. Abstract: This report examines the role of flight simulators in training with a focus on the following key issues: the essence of the pilot's flying skill; the practical problem of simulator fidelity; empirical evidence of simulator training effectiveness as a function of simulated visual capability and motion capability; how training strategies reflect the view of the simulator; and the problem of performance measurement.

with tracking performance. An experiment is cited which exemplified the latter drawback.

Several experiments are adduced which support the view that the size of platform motion effects on pilot performance are so small in comparison with other variables in the training environment--especially subject differences and trial effects--as to be negligible in terms of practical significance, even though the statistical significance may be high.

Airborne studies have revealed that visual sensing can be of finer resolution than vestibular or tactile sensing. Especially for experienced pilots, the case for motion is extremely weak. "At the Flying Training Division of the Air Force Human Resources Laboratory, almost all possible maneuvers and tasks for Instrument, Navigation, Formation, Contact, Air-to-Air, and Air-to-Surface flight have been examined, and as yet not a single one has been found that is not trainable without a platform motion system."

Three transfer-of-training experiments are discussed, in which motion effects were eliminated, and the simulators had low physical and functional fidelity in several other respects. In these cases, transfer to aircraft was excellent, suggesting it was the cognitive components that mattered most; "teaching 'judgement', or more precisely the building of a strategy of flying based on experience, is the critical problem."

The authors conclude that the logical place to teach proper use of motion cues is in the aircraft rather than in the simulator, and that at the state of technology current as of this report, simulators could safely be procured without a platform motion system; and that simulators should be purchased with the largest field of view consistent with mission requirements.

1. Author: Cyrus, Michael L.

2. Title: Motion Systems Role in Flight Simulators for Flying Training

3. Source: AFHRL-TR-78-39, August 1978

4. Topic Keywords: Flight Simulation ; Platform Motion Systems ; Transfer of Training ; Training Effectiveness .

5. Short Summary: A review of the literature pertaining to the effectiveness of platform motion in simulator training concludes that platform motion is not required for the learning of most piloting tasks.

6. Devices:

   a. Advanced Simulator for Pilot Training

   b. LANGLEY Visual-Motion Simulator

   c. Formation Flight Trainer

7. Institutions:

   a. Sponsor: HQ Air Force Human Resources Laboratory (AFSC), Brooks AFB, TX 78235

   b. Performing Organization: Flying Training Division, Air Force Human Resources Laboratory, Williams AFB, AZ 85224

8. Type of Article: Review

9. Abstract: The use of expensive platform motion in simulators for flying training has come under heavy criticism in recent years. This paper reviews literature relevant to the role of platform motion systems in flight training simulators in three areas: ground, airborne, and transfer studies.

The largest volume of research on motion is in single- axis compensatory tracking in ground-based trainers, where the subject attempts to minimize an error initiated by the experimenter, by the instructor, or automatically by the device. Two major drawbacks to platform motion cueing in this environment are identified: (1) its applicability is limited to dealing with control inputs of a random, random-appearing, or transient nature; (2) control system dynamics studied are often very dissimilar to aircraft dynamics, sometimes leading to the interference of simulator motion

A study of the pertinent maintenance tasks, the equipment being maintained, and the courses of instruction, was conducted via a review of literature, on-site visits and interviews, mailed questionnaires, a study of Maintenance Data Collection Records, and a review of two apprentice-level training courses.

The first result of the study was a model of a "Generalized Trainer System" presented in the form of block diagrams; shown in this report is the "Top Level", or overall system diagram. The task analysis yielded data on task frequency and difficulty. The training analysis yielded a six-category classification of course content. A number of alternatives to the present training programs are briefly described.

The concept of developing separate devices for training technical school students and field maintenance personnel rests on two principles:

(1) Basic support skills involve psychomotor skills best learned by "hands-on" training with devices of high physical fidelity.

(2) Troubleshooting is a form of problem solving skill which does not require high fidelity simulation.

Based on these principles, the design models for two devices, a Basic Skills Trainer, and a Specific Skills Troubleshooting Trainer, were described. A third concept, that of a portable "System-Specific Repair Procedures Trainer" is summarized, but no functional specification was prepared.

The authors recommend that the specified trainers be built in prototype and used for training and research purposes.

1. Authors: Condon, Charles F. M., Ames, Lawrence L., Hennessy, John R., & Shriver, Edgar L.

2. Title: Flight Simulator Maintenance Training; Potential Use of State-of-the-Art Simulation Techniques

3. Source: AFHRL-TR-79-19, June 1979

4. Topic Keywords: Flight Simulators ; Maintenance Simulation ; Task Analysis .

5. Short Summary: A study of the need for simulated training for technicians involved in mantaining flight simulators produces models for three prototype maintenance training devices.

6. Devices: None specifically discussed

7. Institutions:

    a. Sponsor: HQ Air Force Human Resources Laboratory (AFSC), Brooks AFB, TX 78235

    b. Performing Organization: Kinton, Inc., 1500 North Beauregard St., Suite 205, Alexandria, VA 22311

8. Type of Article: Theoretical

9. Abstract: Training for maintenance of military flight simulators is hampered by a lack of availability of these devices due to operational field requirements. The objectives of this study were to analyze the responsible maintenance specialties' tasks and their associated training programs, to report potential cost-effective applications of simulation technology to impart the necessary maintenance knowledges and skills, and to provide sets of functional specifications for maintenance simulators.

One problem associated with developing simulation specifications is the lack of knowledge of fidelity requirements. The authors introduce the concept of behavioral fidelity, which "focusses on the replication of man-machine interactions (behaviors) determined as a result of task-analytic procedures." It is observed that "many current approaches to...simulation fidelity were developed with respect to the training of coordinate psychomotor skills...and are insufficient for the development of mental concepts, problem solving ability, and strategy development.... Fidelity of simulation should not be considered as a unitary parameter.... Conceptual skills seem to be especially suited to low fidelity, low cost trainers."

simulator is needed, and if so, what characteristics are required. Products of a front-end analysis include: (1) a listing of task/skill/knowledges to be trainied; (2) an established set of training priorities; and (3) documents that specify the functional requirements of the related hardware, software, and courseware.

Questions addressed in the development of the simulator are: (1) what is the intented scope of the training system; (2) what is the entering skill/knowledge level of the trainee population; (3) what are the deficiencies in existing training; and (4) what is the set of on-the-job procedures that an individual of the designated exit-level skill is expected to execute?

The following prescriptions govern the development of cost-effective simulation:

a. Design to meet, not to exceed, required capabilities; do not overdesign either hardware or software. "Carefully prepared functional specifications can often lead to dramatic reductions in the required fidelity of simulated controls and displays without negatively impacting training effectiveness." Savings are often realized in software by substituting procedural for modelled software.
b. Design fo User Acceptance; since users resist low fidelity in simulation, regardless of its objective merits, it is practical to design in some higher fidelity features where the cost is not excessive.
c. Address current training deficiencies.
d. Provide added instructional capability, to free the instructor from routine tasks, to prevent practice of incorrect responses, and where appropriate, to permit self-paced learning, and to obtain other benefits.
e. Provide appropriate performance measurements.
f. Design for supportability--that is, cost-effective maintenance, expandability/flexibility, and configuration management.

It is noted that research is required to measure transfer of training more accurately, realiably, and meaningfully. Studies done to date have often failed to do all these together.

1. Authors: Clark, C., & Gardner, J.

2. Title: Designing Simulators for Practicality

3. Source: Proceedings of 1977 NTEC Industry Conference, November 15-17, 1977. p. 319; Technical Report: NAVTRAEQUIPCEN IH 294

4. Topic Keywords: Maintenance Simulator Training ; Simulation Fidelity ; Maintenance Simulation .

5. Short Summary: Factors bearing on the practicality of simulation training, in terms of cost-effectiveness, are discussed with an emphasis on resource conservation. Design issues are considered in terms of front-end analysis and a case study of the 6883 Maintenance Training System is presented.

6. Devices: 6883 Simulator System

7. Institutions:

   a. Sponsor: Naval Training Equipment Center, Orlando, FL 32813

   b. Performing Organization: Honeywell Systems and Research Center, Minneapolis, MN 55440

8. Type of Article: Theoretical

9. Abstract: This paper discusses factors bearing on the practicality, in terms of cost-effectiveness, of using simulators in place of actual equipment for maintenance training.

Simulating maintenance equipment offers potential cost savings both in procurement and in maintenance of the training equipment. However, it is also important to recognize that in a training system as a whole, personnel costs usually account for the major portion of the total cost, and simulators have even greater potential to minimize personnel costs associated with their use. Simulator-based training systems can: (1) improve the instructor/student ration, cutting instructor costs; (2) reduce student on-board time; (3) reduce required maintenance force for training equipment; (4) minimize personnel required to incorporate curriculum and/or engineering changes; and (5) reduce required number of field maintenance personnel, thereby reducing the required training throughput.

Simulation should be implemented selectively. A front-end analysis is the crucial first step to determining whether a

(3) "Cost Analysis", which will take into consideration facilities, equipment, instructional material and training of instructors, instructor time, student time and expenses, and "miscellaneous".

At a general level, the experimental design for factors (1) and (2) approximates a "ramdomized controlled field trial" approach. Eight basic treatment groups were defined as follows:

(1) Simulator-trained, simulator-tested, field-assigned to 6883;
(2) Simulator-trained, simulator-tested, field-assigned to other equipment;
(3) Simulator-trained, actual-equipment-tested, field-assigned to 6883;
(4) Simulator-trained, actual equipment-tested, field-assigned to other equipment;
(5) Actual equipment trained, simulator-tested, field assigned to 6883;
(6) Actual equipment trained, simulator-tested, field assigned to other equipment;
(7) Actual equipment trained, Actual equipment tested, field-assigned to 6883;
(8) Actual equipment trained, actual equipment tested, field-assigned to other equipment.

It was planned to select groups randomly from a total of approximately 180 F-111 avionics maintenance trainees during a one-year period.

b. Results: not applicable

c. Author's Conclusion: not applicable

(5) Instructor rating of "activity" or "passivity" of trainee in 2-person team test
(6) Scores of Estimated Job Proficiency Test (pencil and paper)
(7) Subjective ratings of field performance by supervisors

f. Experimental setting/training context: institutional, hands-on

g. Statistical methods: not specified

h. Variables being manipulated:
(1) Training devices: as above section 6
(2) Fidelity Levels (of simulator): not specified
(3) Type of task/skill required: maintenance, cognitive, psychomotor, perceptual, procedural
(4) Task Difficulty: Medium-high

i. Stage of training: not specified

j. Trainee sophistication: not specified

k. Incorporation of device into P.O.I.: presumably lock-step

l. User acceptance or attitude: not discussed

m. Use of Instructional features:
(1) Intensity: assumed will be intensive
(2) Features used: not specified

9. Abstract:

a. Study Synopsis: This report describes a plan for evaluating the cost-effectiveness of a maintenance training simulator in comparison with an actual equipment trainer, on the basis of three factors:

(1) "Simulator Related Issues", referring to how well simulator-trained students acquired skills during schooling, as measured by performance tests (written exams and troubleshooting trials).

(2) "Assessment of Job Proficiency", referring to how well simulator-trained students perform in the field after graduation, as measured by scores on an Estimated Job Proficiency Test, and subjective ratings of performance by supervisors in the field at intervals of 3, 6, and 9 months after schooling.

1. Author: Cicchinelli, Louis F.

2. Title: Avionics Maintenance Training: Relative Effectiveness of 6883 Simulator and Actual Equipment. Test and Evaluation Plan

3. Source: AFHRL-TR-79-13, October 1979

4. Topic Keywords: Maintenance Training .

5. Short Summary: This report describes an evaluation plan which presents eight experimental hypotheses and an accompanying methodology. A cost-analysis outline bearing on the cost-effectiveness of a simulator versus acutal equipment for instruction of F-111 maintenance trainees is also presented.

6. Devices:

   a. 6883 operational test station equipment

   b. 6883 simulator

7. Institutions:

   a. Sponsor: HQ Air Force Human Resources Laboratory (AFSC), Brooks AFB, TX 78235

   b. Performing Organization:
   Denver Research Institute, University of Denver, Denver, CO 80208

8. Type of Article: Methodological (an evaluation plan)

   a. Number of groups: 8 (projected)

   b. Description of Groups:
      (1)-(4) Approximately 20 avionics maintenance trainees each group
      (5)-(8) Controls: approximately 20 same, each group

   c. Tests or trials/timing: 7 post-tests (includes 3 Field Performance Inventory)

   d. Number of different types of measures: 7

   e. Description of measurements and ratings:
      (1) End-of-training-block exam scores
      (2) Accuracy of trouble-shooting solution
      (3) Nature of errors in trouble-shooting task
      (4) Time to completion, trouble-shooting task

Maneuver motion is defined (per Gundry) as "that motion which arises within the control loop and results from pilot-initiated changes....." Disturbance motion, on the other hand, "arises outside the control loop and results from turbulence or from failure of some component of the airframe, equipment, or engines...." Disturbance motion permits more rapid and accurate control under simulated flight conditions in which such motion is appropriate. Maneuver motion is a useful control cue only when the simulated aircraft is unstable, or when an usually stable aircraft is in a particular unstable condition.

With this perspective, the author discusses maneuver motion relative to VTOL aircraft, concluding that maneuver motion is important for training-effective simulation of certain unstable conditions such as the hover mode; however, maneuver motion has not been shown to contribute to transfer of training in stable, easy-to-fly aircraft. "The magnitude of motion in a simulator is probably of less importance than the promptness and correlatedness of such motion."

With regard to disturbance motion, further differentiation is made between uncorrelated disturbance motion--irregular, random, or relatively constant motion such as turbulence or engine vibration--and correlated motion, which is a consequence of events that are of immediate interest to the pilot, such as equipment failure or imbalancing due to jettison, etc. As with maneuver motion cues, the correlatedness of the cues is much more important than magnitude, unless the magnitude of excursion is a significant cue in itself.

It is recommended that correlated disturbance motion cues resulting from aircraft failures and malfunctions and events such as weapons firing, etc., be provided in a training simulator; and that inclusion of some uncorrelated motion cues for manipulating training difficulty might also be useful.

Empiracal research needs to be conducted to investigate these hitherto neglected aspects of motion cuing. Although, if the simulated aircraft is relatively stable, or if the maneuvers being trained are inherently stable, maneuver motion cues would not normally be required, it does not follow that simulated motion cannot contribute to transferable training for unstable flight maneuvers, or for conditions where disturbance motion becomes an important factor.

1. Author: Caro, Paul W.

2. Title: The Relationship between Flight Simulator Motion and Training Requirements

3. Source: Human Factors , 1979, 21(4), 498-501

4. Topic Keywords: Flight simulation ; Platform motion ; Transfer of training .

5. Short Summary: This review of studies made of simulator motion in flight training distinguishes between different types of motion cues. It argues that the investigation of the contribution of important types of motion in training has been neglected in empirical studies to date.

6. Devices: not applicable

7. Institutions:

a. Sponsor: Air Force Office of Scientific Research (NL), Bolling AFB, DC 20332

b. Performing organization: Seville Research Corp., Pensacola, FL 32505

8. Type of Article: Review/Theoretical

9. Abstract: This paper re-evaluates the issue of platform motion in simulation training, by examining the relationship between specific types of motion cues and specific motion-related training ojectives. In line with the distinctions made by Gundry (1976; 1977) between maneuver motion and disturbance motion, the author argues that the many studies which have failed to demonstrate a significant transfer effect from simulated motion in training, may have failed because they emphasize maneuver motion cues in stable aircraft whose contribution to performance is admittedly slight.

A number of studies are cited which support the view that (a) while simulated motion does affect pilot performance in the simulator, and strong correlations have been found between performance in the aircraft and performance in the simulator due to motion, nevertheless (b) simulated motion in training does not benefit transfer performance in the aircraft, or has at best only very marginal effect.

The author explained this paradox with the argument that "regardless of other merits, all such studies have been deficient in that they have not paid sufficient attention to the function and composition of the motion being provided."

learning process has never been developed for simulator training."

Two major problems in simulator testing are: (a) simulator tests ignore training suitability; and (b) poor feedback to the simulator designer. Evaluation of simulators should be focussed primarily on how well they train, and only secondarily on hardware and performance specifications, reliability and maintainability. "Some of the simulators that have been accepted in the past were so poorly suited to training needs that they literally could not be used." With respect to feedback to the designer, "not only is there a need to keep the user in the design process, there is a need to keep the designer aware of the user's activities with the device after it has been put to use."

Four problems are discussed under the heading of Simulator Use: (a) Inattention to Techniques of Simulator Training, which is associated with the lack of a good model of the simulator instructional process. (b) Inadequate Training for Simulator Instructors: instructors are often unfamiliar with instructional techniques and/or how to apply them to instructional features of the simulator. (c) Emphasis Upon Rate of Simulator Utilization, usually in the form of quotas; attempts to fill up simulator time with redundant training is not only wasteful of personnel time, but also generates negative attitudes toward the simulator among instructors and trainees. (d) Inadequate Simulator Cost Effectiveness Data is a managerial problem resulting from incomplete cost- accounting procedures and the lack of an adequate military cost model.

In conclusion, "simulator training is itself part of a much larger training system that includes training in operational vehicles and classrooms and training with supporting resources.... As long as we treat these and other system elements as independent, with responsibilities fractionated, simulator training will continue to be beset with problems of importance equal to or greater than those identified here."

1. Author: Caro, Paul W.

2. Title: Some Current Problems in Simulator Design, Testing and Use

3. Source: HumRRO Professional Paper 2-77, March 1977

4. Topic Keywords: Flight simulation ; Training models ; Behavioral models ; Instructor training ; Managerial problems ; Training effectiveness .

5. Short Summary: A number of conceptual and managerial problems in simulator design, testing, and use are discussed. One of the most serious problems is that, to a great extent, simulators are designed to simulate rather than to train.

6. Devices: not applicable; no specific devices are mentioned

7. Institutions:

a. Sponsor: Air Force Office of Scientific Research (NL), Bolling AFB, DC 20332

b. Performing organization:
Human Resources Research Organization , 300 North Washington Street, Alexandria, VA 22314

8. Type of Article: Conceptual

9. Abstract: While technical problems in development of simulation equipment and associated training programs have received considerable attention, conceptional and managerial problems are the subject matter of this paper. The problems described have been noted by the author as common to all four military services. They are divided among three major phases of the simulator life cycle:
(1) Design Phase
(2) Testing Phase
(3) Use Phase

Two major problems in the Design Phase are: (a) Isolation of the Simulator User; and (b) Inattention to behavioral and Training Models. Designers are specialists who are often out of touch with the user who originally requested the equipment. "In the absence of a strong user influence during the simulator design process, decisions can be made that compromise the future device's training potential." Behavioral and training models are neglected to the extent that simulators are designed to simulate rather than to train. "Unfortunately, a well defined model for the

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The pilot's flying skill is seen as essentially cognitive in nature; his airmanship lies in his ability to "develop mission plans and to use them... Essential pilot skills... represent primarily the operation of his repertory of cognitive processes." The importance of this perspective appears in the discussion of the use of flight simulators for emergency procedures training, wherein a new approach called Situational Emergency Training is shown to focus on training good judgement.

The practical problem of simulator fidelity centers on the diminishing ratio of effectiveness to cost as realism is added. Even if the effectiveness of a high-fidelity simulator were especially high with regard to training any one student on any one maneuver, budgetary and time constraints will limit the number of simulators available and the number of pertinent maneuvers that can be practiced in a training session, and thus reduce the effective throughput of students per dollar and per hour. The "search for higher and higher realism can be self-defeating," and thus the development of simulators must use a different criterion. The transfer-of-training test is recommended as the preferred criterion.

A number of empirical studies of effectiveness using the transfer-of-training model to investigate visual and motion simulation are summarized, with the general conclusions that visual systems are effective and platform motion systems have dubious value. A general critique of this body of research as a whole finds the following shortcomings:

(1) Differences in research objectives between experiments,
(2) Differences in experimental design and control between experiments,
(3) Reliance on subjective judgements of flight instructors as a proficiency measure,
(4) A trend toward small sample sizes, with a consequent reduction in analytic power,
(5) Differences in task selection between experiments,
(6) Lack of generalizability of findings, since each study tends to focus on a specific problem,
(7) Lack of systematic investigation of the relationship between fidelity and effectiveness.

"Because of our current inability to match training and fidelity requirements, it is likely that simulators will continue to be procured under the design goal of maximum fidelity."

Training strategies reflect the view of the simulator either as an aircraft substitute or as an integrated training medium. The latter view fosters a program which uses a variety of media in a sequential progression; it is

exemplified by the American Airlines' Transition and Recurrency programs for Captains and First Officers. The former, non-integrated approach is often flawed by the obvious discrepancies between simulator and aircraft. The "Integrated Approach" discussed in this section parallels the "Least Cost Sequenced Multi-Media Training" described earlier in the report.

The problem of performance measurement is discussed in detail, with special attention to the issue of validity (reliability and sensitivity are also discussed). Consideration is given to two ongoing performance measurement development projects in the U.S. Air Force. Validity is separated into the dimensions of content validity--i.e., how the contents of what is measured match meaningful components of the flight task--and empirical validity, i.e., how well the measurement discriminates between pilots, correlates with concurrent measures, is sensitive to effects of training, and is sensitive to decrements resulting from environmental or pilot stress factors.

Projections of future developments in simulator training programs to include air combat training, and some brief general conclusions round out the report.

1. Authors: Fink, C. Dennis, & Shriver, Edgar L.

2. Title: Simulators for Maintenance Training: Some Issues, Problems, and Areas for Future Research

3. Source: AFHRL-TR-78-27, July 1978

4. Topic Keywords: Maintenance simulation ; Fidelity ; Transfer of training ; Troubleshooting ; General purpose simulators ; Training effectiveness .

5. Short Summary: A review is made of issues and problems in maintenance simulator design and use, and recommendations are made for future research.

6. Devices:

a. ECII/EC-3 Maintenance simulator

b. E-4 Fire control troubleshooting trainer

c. AN/APQ-126 simulator

d. Omnidata simulator

7. Institutions:

a. Sponsor: HQ Air Force Human Resources Laboratory (AFSC), Brook AFB, TX 78235

b. Performing organization: Kinton, Inc., 4660 Kenmore Avenue, Alexandria, VA 22304

8. Type of Article: Review

9. Abstract: This report reviewed past and present applications of simulation to maintenance training, concentrating on the major issues and problems involved. Also, the report identified some of the areas where further research data is required. The report is organized under six major headings:

(1) Simulation Technology as Applied to Technical Training
(2) Application of Simulation Technology to Technical Training: Research Findings
(3) Determination of Simulation Requirements
(4) Design and Specification of Simulation Requirements
(5) User Acceptance of Maintenance Simulators
(6) The Cost-Effectiveness of Maintenance Simulators

A brief historical overview is provided under the first heading, where the major divisions of simulators into

General Purpose vs. Systems-Specific, 2-dimensional vs. 3-dimensional, Prodecural vs. Troubleshooting, and Electronic vs. Non-Electronic, are discussed.

Under the heading of "Application of Simulation Technology to Technical Training: Research Findings," the authors emphasize the demonstrations of effectiveness of generalized, interactive, computer-driven trainers of moderate to low physical fidelity, and also of low-fidelity aids and mock-ups which are not considered "simulators."

The section headed "Determination of Simulation Requirements" summarizes methodology and problems of incompleteness of information, of management, and of transfer-of-training specifications. Transfer-of-Training requirements and therefore training media vary with stages of learning, with low fidelity aids or devices being usually more cost-effective at initial stages of learning.

In the section headed "Design and Specification of Simulation Requirements", it is observed that a body of knowledge still does not exist to predict the effectiveness of a training device. Regarding fidelity requirements, it is agreed that functional or environmental fidelity is of paramount importance, but much disagreement exists over physical or equipment fidelity requirements. "There now seems to be no question but that training devices which possess a reasonable level of functional validity but which have a low physical fidelity can be very effective.... It appears also that a point will be reached beyond which increases in either functional or physical fidelity will not increase training effectiveness."

Intentional deviation from realism is desirable to enhance the teaching capability of simulators (in such features as augmented feedback, etc.).

The role of various groups (e.g., instructors, engineers, and phsychologists) in decision-making is also discussed in this section.

In the section headed "User Acceptance of Maintenance Simulators" it is noted that instructors underuse and misuse simulators because of (1) lack of knowledge of instructional techniques and their proper employment through features of the device; (2) concern that they as instructors are being replaced rather than aided by the device; (3) distrust of devices which are not maximally realistic, i.e., lacking in face validity. These are chiefly management problems.

Under "The Cost Effectiveness of Maintenance Simulators," the authors assert that "the published facts indicate that

the advantages to be gained through the use of maintenance simulator remains a potential; the potential gains have yet to be translated into practical impacts." This results from overtraining, and failures to develop optimal training programs to exploit the advantages of the simulators.

A number of "Suggestions for Future Research" are made at the end of the report. Among other suggestions, a new transfer-of-training research methodology is recommended, to assess the benefits of new simulators more accurately and reliably.

1. Author: Gerathewohl, Siegfrid J.

2. Title: Fidelity of Simulation and Transfer of Training: A Review of the Problem

3. Source: Defense Technical Information Center Technical Report, AM 69-24, December 1969

4. Topic Keywords: Task Fidelity ; Face Validity ; Part-Task ; Whole-Task ; Fidelity ; Transfer of Training ; Motion Simulation ; Kinesthetic Feedback ; Flight Simulation .

5. Short Summary: A review of a number of studies of factors affecting transfer of training from flight simulators to aircraft shows that transfer is generally proportional to the degree of task fidelity and environmental feedback and cuing realism in the simulator. A general scientific theory which accurately predicts optimal fidelity needed for maximal transfer of flight training has not yet been formulated.

6. Devices: Aircraft and Spacecraft Flight Simulators

7. Institutions: Defense Technical Information Center

8. Type of Article: Review

   a. Number of Groups: various experiments reviewed

   b. Description of Groups:

      (1) Subjects: aviators and astronauts

      (2) Controls: not applicable

   c. Tests or Trials/Timing: Varied

   d. Number of Different Types of Measures: Varied

   e. Description of Measurements and Ratings: Varied

   f. Experimental Setting/Training Context: Varied

   g. Statistical Methods: Varied

   h. Variables Being Manipulated:

      (1) Training Devices: Aircraft and Spacecraft Flight simulators of varying fidelity

      (2) Fidelity Levels: High, Medium, Low

(3) Type of Task/Skill Required: Aircraft Flight

(4) Task Difficulty: High

i. Stage of Training: Varied

j. Trainee Sophistication: Varied

k. Incorporation of Device into P.O.I.:

l. User Acceptance or Attitude: Not discussed

m. Use of Instructional Features: Varied

9. Abstract:

a. Study Synopsis: A review of simulation training issues and then-available studies was made to determine (A) what specific elements of simulation fidelity (or "realism") are pertinent to the design and function of training devices; (B) what types of simulation training devices were then available; (C) in what ways various available devices and programs answered the need for specific elements of fidelity.

The heart of the review discussed, and cited experiments relevant to, the following questions:

(1) How "true" should be the visual input which is presented to the pilot in simulated situations?
(2) How closely should the feedback from the controls resemble that of the aircraft?
(3) Are motion cues necessary for operational simulation?
(4) What environmental factors should be included?
(5) What measures are available to determine quantitatively the effect which fidelity of simulation has on the transfer of training?

In addressing the last question, the author noted that quantitative information about the needed degree(s) of fidelity was scarce, and discussed (a) subjective pilot ratings; (b) pilot transfer functions; (c) physiologic measurements; and (d) proficiency measurements, as useful but largely imperfect indicators--the last simply because the functions which determine pilot proficiency in the aircraft had never been measured.

b. Results: A survey of a number of studies of factors affecting transfer of training from flight simulators to aircraft showed that transfer is generally proportional to the degree of task fidelity

and environmental and cuing realism in the simulator.

c. Author's Conclusions: Although part-task simulators are usually less expensive and of lower fidelity than whole- task simulators, they can be very useful for the learning of specific tasks. Their shortcomings can be traced back to the lack of fidelity, particularly in simulating motion. The whole-task flight simulator derives its advantages as a training device primarily from the incorporation of motion cues, if the addition of complex motion vectors increases the fidelity of the situation and does not result in spurious stimuli. It is the psychologic, physiologic, and operational realism which determine fidelity in simulation and not face validity based on physical similarity of the devices.

1. Author: Hays, Robert T.

2. Title: Simulator Fidelity: A Concept Paper

3. Source: U.S. Army Research Institute Technical Report 490, November 1980

4. Topic Keywords: Simulation training ; simulator fidelity .

5. Short Summary: This is both a theoretical and a review paper which, with reference to many sources in the literature of simulation training, seeks to establish a rigorous and useful definition of simulator fidelity. It then applies the definition to several key factors in determining fidelity, and finally proposes a research strategy to investigate empirically the effectiveness of various types of fidelity configurations.

6. Devices: No specific devices discussed

7. Institutions:

a. Sponsor: U.S. Army Research Institute for the Behavioral and Social Sciences (PERI-OU), 5001 Eisenhower Ave., Alexandria, VA 22333

b. Performing Organization: Same

8. Type of article: Conceptual

9. Abstract: This paper addresses two major problems in the understanding of simulator training effectiveness: first, given that the fidelity of the simulator--or degree of its similarity to the operational environment--is a key ingredient in effective training, what is a consistent, unambiguous definition of fidelity that can be meaningfully applied to training devices; secondly, given such a definition, how can researchers determine the kind and degree of fidelity necessary to produce the desired training effect in a cost-effective way?

Many articles are reviewed in which differing concepts of fidelity have been proposed, or employed, by various researchers and contractors. "Equipment fidelity," "environmental fidelity," "psychological fidelity," "task fidelity," "behavioral fidelity," "perceptual fidelity," "functional fidelity," "physical fidelity" are all labels that have been used with varying shades of meaning that overlap and conflict with each other in confusing ways. Out of this jumble, the author selects two terms which are rigorous, in applying exclusively to characteristics of the

equipment rather than to behaviors, and useful, in yielding logical distinctions between two separately influential dimensions of fidelity: these are "physical fidelity" and "funcional fidelity": "Fidelity is the degree of similarity between the simulator and the equipment which is being simulated. It is a measurement of the physical characteristics of the simulator (physical fidelity) and the informational or stimulus and reponse options of the equipment (functional fidelity)."

Reasons for departures from high fidelity in a simulator are summarized as (1) to incorporate "unrealistic" training features such as immediate feedback or enhanced stimulus cues, which aid in training but are not found in the actual equipment; (2) to lower costs; (3) to reduce risk of injury or equipment damage; (4) technological limitations prevent achievement of perfect imitation.

The central question, either in deliberately departing from high fidelity in the interest of training efficiency and cost-effectiveness, or in accepting an unavoidable impairment of fidelity due to technological limitations, is, how do variations in fidelity influence the training effectiveness of the device? This question is complicated by modifications due to many elements of the total training context. Among the more influential of these elements are:

(a) Type of Task. For example, fidelity requirements in teaching the cognitive processes in troubleshooting decision-making can differ from fidelity requirements in psychomotor operation of equipment.

(b) Stage of Learning. Research suggests that lower fidelity is relatively more effective in earlier stages of learning.

(c) Trainee Abilities. High fidelity is wasted on trainees who lack aptitude for the task.

(d) Simulator Use within Training Program, and Attitudes of Instructors and Students.

The relevance of psychological principles of learning to fidelity is discussed, in terms of the need for the trainee's knowledge of results, stimulus-response linkage, motivation, and the phenomenon of perceptual constancy.

To establish general guidelines for determining optimum, cost-effective fidelity levels, empirical investigation of the relationship between level of fidelity and training effectiveness is required. The best avenue of investigation is transfer of training research, but this work is expensive. To maximize the efficiency of this research, the following recommendations are made:

(a) Start by investigating lower levels of fidelity and work upward; quoting Eddowes (1978) "'as soon as the

capabilities of a simulator support practice of a set of training tasks, stop adding to it. Everything else the simulator does will cost more, and while it may not detract from training effectiveness, it probably won't add to it.'"

(b) Use a two-factor research model which isolates the effects of physical fidelity and functional fidelity to the greatest extent possible. A series of studies which used this approach is cited as an example.

(c) Using the two-factor approach, develop scales which would quantify degrees of fidelity and would be applied objectively to various types of equipment.

In summary, the author states, "the proposed definition of fidelity and the research strategy which uses this definition should enable us to quantify the concept of simulator fidelity for any given task. We may then use this data...to prescribe simulator device characteristics.... Our efforts will pay off in more cost effective programs of instruction...."

1. Author: Hays, Robert T.

2. Title: Summary of Major Ideas from Thorpe's Presentation, "Constraints on Fidelity"

3. Source: U.S. Army Research Institute for the Behavioral and Social Sciençes Technical Report 547, "Research Issues in the Determination of Simulator Fidelity: Proceedings of the ARI Sponsored Workshop 23-24 July 1981" November 1981; Robert T. Hays, editor, pp. 57-64

4. Topic Keywords: Engineering Simulation ; Training Simulation ; Fidelity .

5. Short Summary: Several points are summarized which concern the definition and capabilities of simulation, the context of fidelity research, and the constraints placed on the training community by a single "high fidelity" view of fidelity.

6. Devices: None discussed

7. Institutions:

a. Sponsor: U.S. Army Research Institute for the Behavioral and Social Sciences, 5001 Eisenhower Avenue, Alexandria, VA 22333

b. Performing Organization: same

8. Type of Article: Theoretical

9. Abstract: This paper summarizes points made in a presentation by Major Jack Thorpe of the Defense Advanced Research Projects Agency relating to fidelity of simulation in training devices. The most prominent points are as follows:

(1) It is important for researchers in simulation training to distinguish clearly between engineering simulation and training simulation. Engineering simulation requires the highest fidelity possible to the operational situation; cost-effective training simulation requires only the degree of fidelity necessary to elicit the correct learning behavior in the student.

(2) Since training simulators exist in a total training system, interrelated with other components of the system (e.g. instructor, texts, other media), a change in any other system component may affect the simulator and the requirements for fidelity.

(3) A mix of training devices may provide the most effective training. (4) Acceptance of simulation

training may require a public relations effort, and the effect of trainee acceptance of simulators on transfer of training needs to be researched.
(5) Highest fidelity does not always produce the most effective training; "generalizations based on impressions of fidelity or on single cases may not apply to all types of simulation or all training contexts."
(6) Skills that can be trained on simulators fall into three main types: (a) "substitution skills" which can be trained on the actual equipment; (b) emergency procedures and tasks too dangerous to be practiced on actual equipment; (c) skills that are only practiced on the actual equipment during war.
(7) "Fidelity" is not synonymous with "high fidelity". Device fidelity is one ingredient of a total training system, and creative variations in instructional strategies may optimize training even in conditions of low fidelity.

1. Author: Hays, Robert T.

2. Title: Training Simulator Fidelity Guidance: The Iterative Data Base Approach

3. Source: U.S. Army Research Institute for the Behavioral and Social Sciences Technical Report 545, September 1981

4. Topic Keywords: Task Analysis ; Simulator Fidelity ; Iterative Data Base ; Instructional Systems Development .

5. Short Summary: Guidelines are proposed for creating an interactive data base for determining simulator fidelity requirements in the instructional systems development (ISD) process. The paper includes an explication of the way task analysis information is to be translated into fidelity decision- making, and emphasis is placed on the need for an empirical determination of the effects of both additive and subtractive fidelity degradation.

6. Devices: None discussed

7. Institutions:

a. Sponsor: U.S. Army Research Institute for the Behavioral and Social Sciences, 5001 Eisenhower Ave., Alexandria, Va 22333

b. Performing Organization: same

8. Type of Article: Theoretical

9. Abstract: A reliable, unified research data base for determining the required fidelity of simulation, or degree of similarity to actual equipment, is needed to help design and construct cost-effective training simulators. This paper attempts to provide a preliminary organizational framework for a fidelity data base. A working definition of training simulator fidelity is presented which separates fidelity into two dimensions which are characteristics of the hardware itself: physical and functional.

The paper discusses three stages which underlie the organizational framework. First, "the issue of determining the minimum required fidelity for a training simulator (is)... located in its proper place within the context of Instructionsl Systems Development.... Secondly, the necessary information inputs to the fidelity decision process... should be derived from a task analysis.... Finally, a proposed structure for making fidelity decisions (is)... presented."

1. Authors: Hritz, Rohn J., Harris, Hobart T, Smith, Jennifer A., & Purifoy, George R., Jr.

2. Title: Maintenance Training Simulator Design and Acquisition--Handbook of ISD Procedures for Design and Documentation - Vol. 1

3. Source: Draft Tech. Rep. AFHRL Contract No. F33615-78-C-0019

4. Topic Keywords: Transfer of training ; Fidelity ; Maintenance Simulation .

5. Short Summary: This handbook, using flow charts and worksheets as aids, comprehensively guides the process of making decisions on maintenance simulator design and acquisition. A method is presented for determining training requirements, deciding how to meet them, and selecting fidelity levels and feature options.

6. Devices: None discussed

7. Institutions:

a. Sponsor: Air Force Human Resources Laboratory , Technical Training Division, Lowry AFB, CO 80230

b. Performing Organization:
Applied Science Associates, Inc., Valencia, PA 16059

8. Type of Article: Methodological

9. Abstract: This study, one of series of related studies in instructional systems design, provides a method for deriving maintenance training requirements and making training equipment fidelity and instructional features design decisions. Three major decision areas are covered: (1) identifying which training requirements need hardware-type media; (2) the degree of fidelity of equipment components; (3) what instructional features are essential.

All procedures in this report use decision flow charts to increase objectivity and to maximize the consistency and thoroughness of the decision-making. To document all decisions, forms and worksheets have been provided.

The roughly chronological order of the steps in the decision and validation sequence is as follows:

a. Identify system maintenance requirements
b. Identify characteristics of target population
c. Determine training requirements

1. Author: Hritz, Rohn J.

2. Title: Effectiveness Issues

3. Source: U.S. Army Research Institute for the Behavioral and Social Sciences Technical Report 547, "Research Issues in the Determination of Simulator Fidelity: Proceedings of the ARI Sponsored Workshop 23-24 July 1981," November 1981; Robert T. Hays, editor, pp. 83-88

4. Topic Keywords: Training Effectiveness ; Simulation Fidelity .

5. Short Summary: Procedural issues in the development of simulators and simulation training programs are discussed, with an emphasis on the need for finding new methods of evaluating training effectiveness.

6. Devices: None discussed

7. Institutions:

   a. Sponsor: U.S. Army Research Institute for the Behavioral and Social Sciences, 5001 Eisenhower Avenue, Alexandria, VA 22333

   b. Performing Organization: same

8. Type of article: Theoretical

9. Abstract: This brief report discusses procedural issues in the development of simulators and simulation training programs. Design procedures begin with the front-end analysis usually performed at the Tech Sergeant level, and comprises the synthesis of an entire training system as well as the design of the training device(s), which comes down to making separate fidelity decisions on each component. There are losses of information during the process, especially where the procurement specification intervenes between the front-end analysis and the design of the device. Evaluation studies have failed to trace results back to the decision models that were used in determining fidelity and instructional features.

Another shortcoming of device effectiveness evaluation is the reliance of evaluation studies on comparisons between alternative training systems. Now that building alternative training systems has become prohibitively expensive, new ways of evaluating effectiveness need to be developed.

An existing Instructional Systems Design handbook addressing these issues in detail is referred to.

The author points out that "there is a paucity of data on the relationships between simulator fidelity and transfer effectiveness... We don't know very much about how some of the specific features and characteristics commonly built into simulators contribute to or detract from the overall effectiveness... If simulators are to be widely used for training and profit in the future a systematic research program must be conducted to establish the relationships between transfer of training and physical characteristics such as degree and fidelity of simulation."

1. Author: Hopkins, Charles O.

2. Title: Simulators for Training and Profit

3. Source: AFOSR-TR-77-0373; ARL-76-10/AFOSR-76-5, July 1976

4. Topic Keywords: Transfer of Training ; Incremental Transfer ; Cost-Effectiveness ; Fidelity of Simulation ; Platform Motion .

5. Short Summary: A discussion of the cost- effectiveness of training simulators presents a transfer vs. cost ratio model for rational selection and use of simulators. Cited data show a high negative correlation between the cost and reliability of aircraft simulator equipment.

6. Devices: None discussed

7. Institutions:

a. Sponsor: Air Force Office of Scientific Research (NL), Bolling AFB, DC 20332

b. Performing Organization: Aviation Research Laboratory, Institute of Aviation, University of Illinois, Savoy, IL 61874

8. Type of Article: Theoretical

9. Abstract: The escalating cost of simulators without adequate attention to cost-effectiveness threatens to produce a backlash among buyers. One particularly significant cost element--in training program discontinuity as well as in maintenance and repair--is the lack of reliability in costly, high fidelity simulators. This problem is often overlooked. Data are shown which indicate an inverse relationship of reliability to cost, such that in terms of mean flight hours between failures, for example, a $100,000 device is approximately 100 times less reliable than a $1,000 device.

A model for calculating cost-effectiveness developed by Roscoe (1971) and applied to an experiment reported by Jacobs and Roscoe (1975) employs an Incremental Transfer Effectiveness Ratio to depict the relationship between training hours, cost of simulator, and money saved or lost by using the simulator, per increment of ground training time. This model is descriptive rather than predictive: that is, the ratios used are derived from transfer-of-training experiments on the equipment under study.

The advocacy of high engineering fidelity in simulators rests on three arguments: (1) assumptions that the greater the likeness between a simulator and the transfer environment, the greater the transfer of training; (2) trainees are more highly notivated by a very realistic simulator; (3) pilots find higher fidelity more acceptable. The first argument has been anaswered by research which shows that not all degradations in fidelity result in degradation of transfer performance (the reverse is sometimes true). The second argument is beside the point; the point is not how enthusiastically the trainee flies the simulator, but how well he/she flies the real aircraft after simulator training. The last argument may be dealt with in practice by "management of reinforcement contingencies"; that is, by finding motivations for pilots to use the simulator apart from their feelings about realism.

If the training community fails to restrain the trend toward unnecessary, costly increases in realism in simulators, a backlash against all simulators may result.

1. Author: Hopkins, Charles O.

2. Title: How Much Should You Pay For That Box?

3. Source: Human Factors , 1975, 17(6), 533-541

4. Topic Keywords: Fidelity of Simulation ; Cost-Effectiveness ; Flight Simulation .

5. Short Summary: The high cost of maximum fidelity in flight simulators has not been experimentally justified, and personnel in the simulator training field must anticipate eventual backlash from the trend toward costly and probably unnecessary increments in realism.

6. Devices:

   a. L-1011 (mentioned)

   b. F-4J (mentioned)

7. Institutions:

   a. Sponsor: Air Force Office of Scientific Research , Office of Naval Research ,FAA, and Air Force Avionics Laboratory

   b. Performing Organization: Aviation Research Laboratory (ARL), Institute of Aviation, University of Illinois at Urbana-Champaign

8. Type of Article: Review

9. Abstract: "More" is not necessarily "better" when it comes to increasing realism, or fidelity, in a flight training simulator, if transfer of training to the operational aircraft is the criterion. First of all, "the single most important factor that influences the effectivness of a simulator in a training program is how it is used." Secondly, research has not shown, for example, that the addition of such "realistic" features as platform motion in a simulator, once generally accepted, enhances subsequent trainee performance in the aircraft, even though it may enhance performance in the simulator. Thirdly, even if the addition of a feature enhances transfer, the question of its cost-effectiveness must be considered. Studies using a comparative cost instrument such as Roscoe's (1972) Incremental Transfer Effectiveness Ratio are needed to vindicate the great cost increases resulting from the attainment of extremely high fidelity. "In certain cases there may even be a negative relationship between effectiveness and the inclusion of a costly feature."

These studies focussing primarily on verbal rote memorization yielded little evidence of general ability enhancement.

(2) "Warm-Up", in which a subject is prepared for performance of a task, such as verbal recall, by exercises in a related but nonidentical task, has some implications for ability training, relating to the "set" of preparatory postural and attentional adjustments that facilitate performance.

(3) "Learning to Learn" studies have given some support to the concept of nonspecific transfer, through the inference that generalized strategies, or "learning sets" may facilitate performance across a range of tasks within a certain class. At least one investigation indicates that "learning to learn" phenomena are at work in perceptual-motor as well as verbal learning.

Studies of task characteristics and conditions of practice and the use of cognitive strategies suggest that, depending on the kind and duration of practice, and the amount of abstraction required, nonspecific transfer has taken place between different tasks in verbal and pattern recognition, when the performer has been able to perceive commonalities among the training tasks.

Applied research in the field of low fidelity simulation training has also suggested the enhancement of nonspecific skills, if not abilities. Also some evidence of training originality and creativity has been reported, but is not conclusive; research in training cognitive abilities has been still less conclusive.

This review suggests that there is some indirect evidence to support the notion that abilities can be trained. Three important considerations from research support this idea:

(a) task characteristics tend to be more predictive of transfer than just the training materials themselves;
(b) variability of training or practice within a class of response types facilitates positive transfer;
(c) transfer may, in part, be mediated by a strategy requiring abstraction of important features in training.

As to the more general question of abilities training, a revision may be in order for the traditional conception of "ability" as "a fairly enduring trait, which in the adult is relatively difficult to change." Conceivably, this conception of ability might be left intact, modified, however, by the exploration of training strategies to evoke the potential of the abilities in greater degrees of power and versatility.

1. Author: Hogan, Joyce C.

2. Title: Trainability of Abilities: A Review of Nonspecific Transfer Issues Relevant to Ability Training

3. Source: Advanced Research Resources Organization Technical Report, January 1978

4. Topic Keywords: Trainability ; Learning to Learn .

5. Short Summary: A review of literature pertaining to nonspecific transfer issues finds some indirect evidence that abilities can be trained. It concludes that transfer of training can be enhanced by greater emphasis on task characteristics, on variability of training within a class, and on a mediation strategy that requires abstraction of important features in training.

6. Devices: None discussed

7. Institutions:

a. Sponsor: Personnel and Training Research Programs, Office of Naval Research (Code 458), Arlington, VA 22217

b. Performing Organization: Advanced Research Resources Organization, 4330 East-West Highway, Washington, DC 20014

8. Type of Article: Theoretical/Review

9. Abstract: "The degree to which basic human abilities are trainable is a question posed nearly 90 years ago that remains relatively unanswered." This is one of the author's conclusions at the end of a review of a number of research efforts and hypotheses that have touched on the area of nonspecific training. As a working definition, the term "ability" refers in this paper to "empirically determined relations among separate observed performances.... Skills are more specific, and define levels of proficiency in particular tasks. These skills can be described in terms of component abilities required to perform them, with certain abilities shown to underly performance in many superficially different human tasks."

With this in mind, the author surveys studies in which nonspecific transfer of learning across different tasks has been investigated. These studies fall into three major categories:

(1) General Memory Ability is perhaps the earliest line of research, beginning with William James in 1890.

equipment." Simulator training is seen as a part of a program which also includes: classroom lectures, books/slides/movies, operational demonstration, operational equipment practice, and on the job training.

While simulator training problems do not greatly differ from other training problems in a functional sense, the uniqueness of simulator problems accrues from the complexity, sophistication, and cost of simulation equipment and its use. In the interests of cost effectiveness, the design of equipment must emphasize training effectiveness rather than the sheer realism of the device. The major question to answer is, "what are the critical skills that the training device is supposed to facilitate?"

The following topics are discussed in relation to training effectiveness: (1) establishment of training goals; (2) training strategy and training program organization; (3) instructional methods and training procedures; (4) learning of perceptual motor skills; (5) performance measurement.

The problem of performance measurement deserves closer attention than is generally given. Important questions pertinent to performance measurement are: what to measure, what are the purposes of the measurement, reference values for error measurement, criteria for good and bad performance, the practical importance of measurable differences, and the question of equivalence of two training methods when they do not produce reliable differences in performance.

The problem of measuring transfer of training reflects the inadequate understanding of the relationship between performance in training and performance in the operational situation. The incremental transfer effectiveness function is recommended over the Transfer Effectiveness Ratio or the Percent of Transfer inasmuch as it "reveals the training value of each additional hour or trial of training" rather than an average value per hour or trial.

Research and development of a theoretical system necessary to define and measure the behavioral processes which mediate between task and device variables and performance have not yet been done. "If the necessary fundamental research is performed and results in the understanding of these intervening processes, then I believe the issues of simulator fidelity, similarity and realism will disappear."

1. Author: Hennessy, Robert T.

2. Title: Problems in Simulation for Training

3. Source: U.S. Army Research Institute for Behavioral and Social Sciences Technical Report 547, "Research Issues in the Determination of Simulator Fidelity: Proceedings of the ARI Sponsored Workshop 23-24 July 1981"; Robert T. Hays, editor

4. Topic Keywords: Transfer of Training ; Instructional Methods ; Training Effectiveness ; Incremental Transfer Effectiveness Function ; Simulator Fidelity .

5. Short Summary: Problems in simulation for training are considered within the overall framework of the complete training program. The paper concludes that simulation fidelity issues can only be resolved by fundamental research into behavioral variables, and development of a theoretical system to relate physical task/device variables to performance variables by some set of conceptualized intervening processes.

6. Devices: None discussed

7. Institutions:

a. Sponsor: U.S. Army Research Institute for the Behavioral and Social Sciences, 5001 Eisenhower Avenue, Alexandria, VA 22333

b. Performing Organization: Same

8. Type of Article: Theoretical

9. Abstract: In this paper the issue of fidelity in simulation equipment is viewed as subordinate to behavioral issues in training. Among the theoretical and methodological issues posed by Gagne twenty-seven years ago which have not received enough attention are: the structure of skills determinants of human variability, set, motivation, and transfer of learning; and task behavior analyses for training, proficiency measurement, and criterion development.

The author believes that simulation research "often takes the form of comparative evaluation of different levels of simulator technology." Therefore he focusses on the overall problems of training within which the design of simulation equipment is embedded. "There are other means for getting more training per dollar than improving simulation

ISD process produced the idea of employing a "training device facilitator" who would perform a role analogous to a Department of Agriculture extension agent; one who would communicate with device users, device engineers, researchers and training experts, and "provide a vital communications link between individuals who may only be concerned with narrow problems, but who could operate more effectively with a better overview of the whole ISD process."

Ideas for unifying empirical research which emerged from the workshop were: (1) Taking a whole-system approach; (2) include basic research on the mental models of both trainees and instructors; (3) include research on the interaction of levels of fidelity and device configurations with a large variety of variables such as task difficulty, etc.; (4) organize research to produce data usable by diverse groups; (5) organize so that later efforts can build on previous research.

The relationship between fidelity and device effectiveness remains in need of a prescriptive, predictive model which can only come out of extensive research oriented in a unified way toward that goal. Transfer of training research was agreed upon as the most reliable evaluative tool, but Transfer of Training studies so far have not yielded either a predictive model for the design of future devices, or a method to evaluate the teaching of skills on a simulator which cannot be practiced on the operational equipment and therefore are not subject to transfer-of- training studies. Possibly fruitful areas of research that impinge on device effectiveness were discussed under the headings of control strategies, failures in simulator training, performance measurement, and simulator instructors.

Other suggestions coming from the workshop dealt with the use of new instructional technologies by instructors and students, ways of obtaining funds for needed research, and criteria for prioritizing among research issues.

definition of fidelity, represented at one end by the view that only the physical and functional dimensions of fidelity--fidelity as hardware specifications--were the essentially meaningful dimensions to evaluate, represented at the other end by the view that multiple types of fidelity-- e.g., task, perceptual, etc.--needed to be discussed. The second view rejects the attempt to develop a linear metric for fidelity, and suggests instead using a "branch-and- flowchart identifying the categories and procedures of various aspects of fidelity which apply to the situation." Hays recommends that "we can best proceed by dealing with fidelity as the physical and functional aspects of the training device and treat other 'types' of fidelity as classes of variables which interact with these aspects of the device hardware."

The second continuum of views on fidelity was of the usefulness of the fidelity concept itself; at one end was the view that fidelity was a non-issue, at the other the view that it was the most important issue. Three objections to placing importance on the question of fidelity were brought forward in the working group sessions:

(1) Focussing on fidelity takes emphasis away from the more important issues of "who is going to be trained, for what, what type of training program, what type of environment, what does the task consist of, how will we determine when the task has been adequately trained... if you deal with those issues, then the fidelity question seems to be taken care of."

(2) So many ways of measuring fidelity or similarity exist as to make the concept meaningless on a theoretical basis;

(3) Since device fidelity requirements change as the equipment being simulated changes, fidelity is too changeable, over time, to pin down specifically.

Those who would devalue fidelity recommended the following alternatives for increasing training device effectiveness: (a) historical studies; (b) handbooks; (c) enhancing corporate memory or experience; (d) altering the reinforcements for designers and procurers; (e) emphasize back-end analysis; (f) provide examples of good inexpensive training devices; (g) analytical techniques to define simulator training needs for engineers.

Hays maintained that the pro and con viewpoints on fidelity can be reconciled by treating fidelity as a summary concept; "the most important thing to remember about the concept of fidelity is to use it as a tool, but not to let it dictate to the user how it should be used."

Discussion of communication among different "players" in the

1. Authors: Hays, Robert T., Holman, Garvin L., Houston, Thomas J., Klein, Gary A., & Swezey, Robert W.

2. Title: Research Issues in the Determination of Simulator Fidelity: Proceedings of the ARI Sponsored Workshop 23-24 July 1981: Goals and Organization; Summaries of Topic Areas in the Working Group Sessions; and Summary Comments

3. Source: U.S. Army Research Institute for the Behavioral and Social Sciences Technical Report 547, Robert T. Hays, editor; pp. 1-8, 121-142, 159-166

4. Topic Keywords: Training Effectiveness ; Transfer of Training ; Simulation Training ; Simulator Fidelity .

5. Short Summary: In the ARI sponsored workshop, a range of opinions on the relationship between simulator fidelity and training effectiveness are discussed, and recommendations are made as to how to perform research to clarify these issues.

6. Devices: None discussed

7. Institutions:

a. Sponsor: U.S. Army Research Institute for the Behavioral and Social Sciences, 5001 Eisenhower Avenue, Alexandria, VA 22333

b. Performing Organization: same

8. Type of Article: Theoretical

9. Abstract: A workshop held at the Army Institute in Alexandria, VA in July 1981 was attended by 67 personnel including Army, Navy, and Air Force uniformed representatives, and civilian representatives from industry, government, and academia. "The goal of the workshop was to define and prioritize research issues for a program of empirical research on the relationship between simulator fidelity and training effectiveness."

This synopsis covers the portions of the report on the workshop comprising the summaries of topic area discussions in working group sessions, and summary comments on the entire workshop by Robert T. Hays.

In his summary comments, Hays observes that workshop participants viewed the fidelity issue along two different continua. The first continuum was that of the meaning or

It is noted that specifying training fidelity is just one portion of the entire Instructional Systems Development process, taking place in the middle development phase, and only if prior design decisions have selected a simulator as the training medium.

The task analysis which forms a first step in the process is the best source of information on which to base fidelity decisions. Six different types of task analysis are identified, of which any one, taken alone, is ordinarily not sufficient for making all necessary decisions. A table listing required elements of task analysis output--which may draw on several types of task analysis--is given, to guide the extraction of information; "if all the information... is not available from a single method of task analysis, other methods should be employed until the information is obtained."

Other tables and a task analysis worksheet are shown, to outline and illustrate methods for translating the output of the task analysis into specific fidelity recommendations. During this process the expert must make decisions based on knowledge of the effects of device characteristics on training effectiveness. "The task analysis may only tell us the broad outline of the task as it is accomplished in actual field conditions. It does not tell us how to effectively train people for that task." This is where the need for a research data base relating fidelity to training effectiveness is essential. There are no simple relationships between fidelity and effectiveness; variables such as stage of training, task difficulty, and others all influence the relationship. Thus "the proposed simulator fidelity data base should contain data on all of the variables which interact with simulator fidelity to produce a given amount of training effectiveness."

Furthermore, "reduced simulator fidelity may arise from additions to as well as subtractions from actual equipment features. Fidelity research must... empirically determine the relative effects of these two types of fidelity degradation... additive and subtractive...."

Finally, the author recommends that "research efforts begin with simple questions.... Only when data have been obtained from the simple designs should more complex designs be studied.... It is vital that the empirical data be accumulated in a systematic manner."

d. Determine type of technical training materials required
e. Sequence skills and knowledge
f. Identify fidelity and simulated features
g. Select instructional features
h. Prepare ISD specification
i. Identify method
j. Prepare course control documents
k. Prepare instructional materials and tests
l. Validate instructions
m. Continue training
n. Evaluate training

Under each step, substeps are explained in concrete detail, using examples where helpful, to guide the designer through all tributaries of the decision-making system.

This study emphasizes the importance of identifying the skills and knowledges required as parts of the total task which is being trained. An explicit taxonomy of skills and knowledges is presented. The breakdown of tasks into skills and knowledges has a direct bearing on fidelity requirements: "Often many of the skills and knowledge that make up a task do not need to be taught on high-fidelity equipment even when the other skills and knowledge that are part of the task do." The procedures described in the handbook assist the designer to match fidelity requirements with specific skills and knowledges, and thus to avoid the costly fidelity "overkill" that results from analyzing fidelity requirements at the task level only.

Further steps go on to integrate component fidelity needs found at the skill and knowledge level into the task level and, further, into the task-group level.

The fidelity question is subdivided into stimulus, response, and feedback concerns; a flow chart is provided to illustrate the interrelationship between these concerns.

A list of low-fidelity alternatives, e.g., mock-ups, tapes, films, is also provided.

1. Authors: Hritz, Rohn J., & Purifoy, George R. Jr.

2. Title: Maintenance Training Simulator Design and Acquisition

3. Source: Final Report, AFHRL-TR-80-23 August 1980

4. Topic Keywords: Maintenance Training ; Maintenance Simulation ; Training Devices ; Simulator Design .

5. Short Summary: This report summarizes activities and results of a project which produced models and guides for meeting maintenance training requirements with appropriate training devices. The procedures for determining when to use a simulator, and what degree of simulation it should possess, and what features it should incorporate, are discussed, along with nine problem areas and recommended solutions to each.

6. Devices: None discussed

7. Institutions:

a. Sponsor: HQ Air Force Human Resources Laboratory (AFSC), Brooks AFB, TX 78235

b. Performing Organization:
Applied Science Associates, Inc., Box 158, Valencia, PA 16059

8. Type of Article: Review

9. Abstract: This report summarizes activities and results of a project which produced models and guides for answering maintenance training requirements with appropriate training devices. The report (a) describes the research activities that were performed; (b) describes the products and reports produced and the reactions of the intended audiences to these products; and (c) presents a list of problem areas, recommendations, and areas for future research.

The basic problem being addressed was the inadequacy of information being supplied to fabricators of training requirements. It was felt that better guidance for Instructional Systems Development (ISD) analysts and device procurement personnel would help correct these inadequacies. The research activities that were performed focussed on procedures for "designing and documenting maintenance trainers: i.e., the procedures for determining when to use a simulator, the procedures for determining the degree of fidelity of the trainer components, and the procedures for

selecting and defining the instructional features of the maintenance trainer."

The analysis, clarification, and expansion of procedures resulted in four documents: (1) "Maintenance Training Simulator Design and Acquisition: Summary of Current Procedures" AFHRL-TR-79-23, November 1979; (2) "Maintenance Training Simulator Design and Acquisition: Handbook of ISD Procedures for Design and Documentation"; (3) "Maintenance Training Simulator Design and Acquisition: ISD-Derived Training Equipment Design"; (4) "Maintenance Training Simulator Design and Acquisition: Prime Development Specification for Maintenance Training Simulatore." The model or generic specifications presented in the last three documents, adaptable to all kinds of maintenance training devices, provide systematic and detailed "fill in the blanks" type guidance for identifying training objectives, target populations, device characteristics and fidelity requirements, and other items pertinent to device design.

Reactions to the documents cited above were obtained, problem areas were identified, and recommendations were made for improvement. The nine problem areas are summarized as follows: (1) Pressure on the ISD analyst to accelerate the acquisition cycle; (2) Lack of continual communication between ISD and device procurement personnel; (3) transfers of ISD personnel before their expertise has been fully realized; (4) need for better exposure to "state-of-the-art" devices; (5) translation of engineering changes in operational equipment to the trainer; (6) need to integrate different procedural handbooks into one document; (7) need to design contractor-provided data base; (8) need for Instructional Features scenarios; (9) specialists/experts should closely review certain parts of the device specifications before they are submitted to the contractor.

1. Authors: Hritz, Rohn J., & Purifoy, George R. Jr.

2. Title: Maintenance Training Simulator Design and Acquisition: ISD-Derived Training Equipment Design

3. Source: Technical Report, AFHRL-TR-81-52, February 1982

4. Topic Keywords: Training Devices ; Maintenance Simulation ; Systems Management ; Fidelity .

5. Short Summary: This paper presents a model for documenting training equipment designs derived from an Instructional Systems Development analysis. The model standardizes the communication between ISD and Simulator System Program Office Personnel. The authors outline a method for communicating a training device design to the simulator system program office once the need for such a device has been established by ISD analysis.

6. Devices: None discussed

7. Institutions:

a. Sponsor: HQ Air Force Human Resources Laboratory , Brooks AFB, TX 78235

b. Performing Organization:
Applied Science Associates, Inc., Valencia, PA 16059

8. Type of Article: Methodological (a procedural guide)

9. Abstract: This technical paper presents a model for standardizing communications between Air Force Instructional Systems Development (ISD) personnel and Simulator System Program Office (SIMSPO) personnel, in the design of maintenance training devices. The body of the paper outlines training device design data requirements in a systematic way so that all the ISD analyst need do is fill in the blanks provided. An appendix supplies instructions for applying the model. Using the model, ISD analysts will specify such design information as: (1) characteristics of the target population and who will use the trainer; (2) a list of the training objectives to be achieved using the trainer; (3) a list of the tasks to be practiced and/or acquired on the trainer and a list of malfunctions to be presented; (4) a scenario discussing how the trainer will be used to achieve the objectives; (5) a list of the physical and functional characteristics of the components to be represented on the trainer (with illustrations where possible); (6) a description of the instructional features required on the trainer. Some of this information, such as specifications of the characteristics of the target

population, are optional.

It is recognized that completion of the design is an iterative process and that, in view of real-world time constraints, the model may be completed in stages.

The decision-making procedures which lead to the design specifications in the model are not contained in this paper, but rather in other ISD procedural handbooks, in particular "Maintenance Training Simulator Design and Acquisition--Handbook of ISD Procedures for Design and Documentation" by Hritz, Harris, Smith, and Purifoy, AFHRL-TR-81-51, 1980.

1. Authors: Hritz, Rohn J., Purifoy, George R. Jr., & Fitzpatrick, Jean

2. Title: Prime (Item) Development Specifications for Maintenance Training Simulator: Model Specifications Volume I & II, final draft

3. Source: Applied Science Associates, Inc., Valencia, PA 16059, April 1981

4. Topic Keywords: Maintenance Training ; Maintenance Simulation ; Training Devices .

5. Short Summary: This procedural guide provides a generic specification format that can be adapted to specification of requirements for any type of maintenance trainer and is tailored for use by the Air Force System Program Office.

6. Devices: None discussed

7. Institutions:

   a. Sponsor: HQ Air Force Human Resources Laboratory (AFSC), Brooks AFB, TX 78235

   b. Performing Organization: Applied Science Associates, Valencia, PA 16059

8. Type of Article: Methodological (a procedural guide)

9. Abstract: This report contains a model or generic specification for maintenance training equipment. It is divided into two volumes: Volume I contains the model; Volume II, the Appendix/Handbook, contains instructions for tailoring the paragraphs and subparagraphs in the model specification for a specific application. Volume I has blanks to be completed by personnel at the Air Force Simulator System Program Office; Volume II provides instructions for completing the blanks. The model specification contains paragraphs and subparagraphs which specify both training requirements and engineering requirements.

Contents of Volume I include a total of approximately 200 line items of specifications under the following headings: (General) Description, Characteristics, Design and Construction, Logistics, Personnel and Training, Quality Assurance Program, and Preparation for Delivery.

Contents of Volume II include, for each of the approximately 200 line items of specifications, Rationale and Guidance, Performance Parameters, Background and Sources, and Lessons

Learned.

These specifications are best used in combination with documentation prepared by an Instructional Systems Development analyst as described in "Maintenance Training Simulator Design and Acquisition: ISD-Derived Training Equipment Design," prepared by Hritz and Purifoy (AFHRL-TR-81-52, February 1982).

1. Authors: Huddleston, H. F., & Rolfe, J. M.

2. Title: Behavioral Factors influencing the use of flight simulators for training

3. Source: Applied Ergonomics, September 1971, pp. 141-148

4. Topic Ke; vords: Flight simulation ; Transfer of learning .

5. Short Summary: A review article, briefly summarizing several issues in the use of flight simulators emphasizes the role of a simulator as a training aid rather than total training device. At the same time, it enumerates the drawbacks of training solely in flight.

6. Device: None discussed

7. Institutions:

a. Sponsor: Royal Air Institute of Aviation Medicine, Farnborough, Hampshire, England

b. Performing organization: same

8. Type of article: Review

9. Abstract: This paper reviews literature on the use of flight simulators, and propounds the view of a simulator as a training aid rather than a total training environment.

A transfer effectiveness model, and the influence of the training organization as a whole on the simulator training program are discussed. Maximal use of the simulator can conflict with the need to keep motivation high in training; "the problem is... to determine the correct ratio of flying hours to simulator hours in order that training effectiveness and aircrew motivation (both) be preserved in... training environments."

Demands on instructors are also considered. Device training may require so much work of an instructor in running the simulation, that he/she has little time to "instruct".

Several issues that bear on fidelity requirements are discussed. There is a need for research to more fully determine what are the behavioral strategies used in real flight which need to be elicited by the simulator, and what are the sensory threshholds of various stimuli that cue the behaviors. Furtherfore, research is needed to determine the variations in proportions of sub-task constituting the

entire workload, as function of flight phase and environmental conditions.

Information flow models are described which depict the relationship between subject, controller, and machine via feedback loops in the simulator.

The requirement for perceptual fidelity in the device is conceived as a question of determining the point of diminishing returns: "the key question concerns the point at which we stop adding items of simulator hardware which, taken singly, demonstrably add to the catalogue of sensations simulated."

1. Authors: Huff, Edward M., & Nagel, David C.

2. Title: Psychological Aspects of Aeronautical Flight Simulation

3. Source: American Psychologist, 1975, March, 30(3), 426-439

4. Topic Keywords: Flight Simulation ; Research Simulators .

5. Short Summary: This review paper discusses theoretical design issues in the current evolution of flight simulators. It focuses on ways of conceptualizing and measuring pilot experiences during the implementation of research programs. It is suggested that the theory of signal detectability and nonmetric multidimensional scaling techniques be applied to help build a foundation for a science of simulation.

6. Devices: Several devices are mentioned with respect to design features but not with respect to effectiveness.

7. Institutions:

a. Sponsor: NASA

b. Performing organization: Man-Machine Integration Branch, NASA, Ames Research Center, Moffett Field, CA 94035

8. Type of Article: Theoretical

9. Abstract: This paper discusses issues in the development of ground-based flight simulators for research purposes, without regard to training effectiveness. A difference is noted in technical requirements between research simulators and training simulators, of which one aspect, for example, is the generally lower degree of cockpit fidelity in research devices, due to the need for flexibility in simulating a variety of aircraft.

The principal components of a flight simulator are discussed in turn: the cockpit, the visual subsystem, motion subsystem, and computer control device. In the discussion of these components, the following issues relevant to unresolved questions in both research and training simulation are raised:

(a) Contradictory data have been found regarding the relative contribution of visual and motion cues to pilot performance in simulators. It is unknown, for example, why a pilot in simulation tends to land shorter on a runway than in real flight; one

experiment suggests that insufficient motion cues are more to blame than inadequate visual systems. Two somewhat differing views of spatial perception-- one emphasizing the interaction between optic arrays, the other emphasizing the internal interpretive models of the observer--are adduced by way of illumination, but the authors note that no systematic tests of these notions have been conducted.

Empirical studies of simulated motion effects on pilot performance have produced ambiguous findings. We do not know what subtle interactive effects motion and vision cues may have on the complex imformation processing performed by the pilots of simulated aircraft.

(b) The impact of simulation fidelity (that is, the adequacy of perceptual effects induced by the simulator as a result of engineering and construction) on simulator validity (that is, the generalizability of simulator effects on the pilot to the real flight situation) is based on a prior assumptions which place a high value on realism. Many researchers feel that simulation validity may be operationally defined by the extent of which simulated system performance corresponds with that obtained from a real aircraft. Informed pilot opinion is also relied upon as a measure of validity. However, the individual pilot has personal biases and his view is restricted to aircraft for which he has sufficient experience to make a comparison.

Thus it is a fundamental problem to assess the extent to which engineering "improvements" are relected in increased psychological realism. Research to date has been primarily concerned with the effects of improved engineering on overall simulator validity, rather than witn measurements of psycho-physical relationships and perceptual processes influenced by various subsystem designs.

(c) Two techniques are suggested to help build a foundation for a science of simulation:

(i) The theory of signal detectability, which can be applied wherever binary decisions are made in the face of subjective uncertainty;

(ii) Nometric multidimensional scaling techniques, particularly those used to characterize individual differences in the response to complex perceptual stimuli.

A plea is made to develop systematic research programs to produce principles of simulation to deal with these and related problems.

1. Authors: Iffland, Harold L., & Whiteside, George A.

2. Title: Aircraft Simulator Data Requirements Study, Vol. II

3. Source: ASD-TR-77-25 Volume II, January 1977

4. Topic Keywords: Simulator Data Requirments ; Flight Simulators ; Air Weapon System Design Data ; Computer-Aided Design .

5. Short Summary: A survey of flight simulator manufacturers, simulator acquisition activities, and aircraft manufacturers, yields criteria of a General Requirement for supplying data for simulator development.

6. Devices: None discussed

7. Institutions:

a. Sponsor: Aeronautical Systems Division, Wright-Patterson Air Force Base, OH 45433

b. Performing Organization:
Systems Research Laboratories, Inc., 2800 Indian Ripple Road, Dayton, OH 45440

8. Type of Article: Theoretical

9. Abstract: Impediments to the flow of data on new aircraft to simulator manufacturers, and suggestions for overcoming them, constitute the subject matter of this report. The contents of this volume are summarized in the paper by Whiteside, George A. entitled "Aircraft Simulator Data Requirements Study: Executive Summary" ASD-TR-77-25 Vol. I.

A survey of flight simulator manufacturers, simulator acquisition activities, and aircraft manufacturers was performed to determine a General Requirement for supplying the necessary data for simulator development on a schedule such that "the simulator can be on-site, ready for training before the first production aircraft is delivered to the operating command."

Discussion of the survey touches on the following topics and problems in the acquisition of data for simulation: acceptance test procedures; malfunction and abnormal operations; barriers to communication between simulator manufacturer and aircraft design engineers; timing of physical data, aerodynamic data estimate, system data estimates, "hot bench" tests, and dynamic tests;

intelligence data; tactical program tapes and duplication of aircraft central computers; enforcement of the data-acquisition schedule; procurement of crew station parts from the aircraft manufacturer; project pilots and project crew members; and role of instructor pilots.

A number of specific recommendtions are made to facilitate the supplying of useable data to the simulator manufacturer. The primary recommendtions are, that the initial contract for aircraft development should require delivery of the data needed to develop a full mission simulator, and that the activity should follow up on these requirements to ensure a timely delivery of accurate information. The Air Force Flight Test Center must also be tasked to provide handling qualities and performance parameters to the simulator manufacturer as early as possible in the test program; the AFTC should also assign a qualified test pilot curent in the aircraft, and a flight test engineer, to assist in the development of the simulator.

1. Authors: Isley, Robert N., Corley, Winon E., & Caro, Paul W.

2. Title: The Development of U.S. Coast Guard Aviation Synthetic Training Equipment and Training Programs

3. Source: HumRRO-FR-D6-74-4, October 1974

4. Topic Keywords: Flight Simulation ; Rotary Wing Training Requirements ; Variable Cockpit Training System ; Cost-Effectiveness .

5. Short Summary: This paper describes a three-phase study in the development of a synthetic training and academic training program for U.S. Coast Guard helicopter pilots. A before-and-after Cost Benefit comparison shows savings through use of the new programs.

6. Devices: Variable Cockpit Training Devices for HH-2A and HH3F helicopters

7. Institutions:

a. Sponsor: Department of Transportation, U.S. Coast Guard, 400 Seventh Street, S.W., Washington, DC 20590

b. Performing Organization: Human Resources Research Organization , 300 North Washington Street, Alexandria, VA 22314

8. Type of Article: Review

9. Abstract: This paper describes the latter two of three phases in the development and implementation of synthetic and academic flight training programs for the U.S. Coast Guard. Programs were developed using simulators for two helicopters, the HH52A and HH3F, with a focus on training qualified pilots to perform Search-and-Rescue Operations. A qualification program for fixed-wing pilots transitioning to the HH52A was also developed, along with an Instrument Proficiency program for operational helicopter pilots in both helicopters, and a Transition program for helicopter pilots, principally those just out of Undergraduate Pilot Training, to learn to fly the two helicopters.

A before-and-after Cost Benefit Comparison is given which indicates substantial savings through use of the new programs, using primarily simulators, in contrast with the former program which used operational equipment in training. It was calculated that the cost of the simulators plus the associated training programs would be paid back within 14 to

1. Author: Miller, Robert B.

2. Title: Handbook on Training and Training Equipment Design

3. Source: WADC Technical Report 53-136, June 1953

4. Topic Keywords: Transfer of Training ; Training Effectiveness ; Simulation ; Knowledge of Results ; Learning Feedback ; Action Feedback ; Motivation Feedback ; Psychological Set ; Overlearning ; Stimulus-Response .

5. Short Summary: The handbook provides a detailed and comprehensive discussion of issues relevant to the design and use of training equipment, with an emphasis on applying the psychological principles of human learning.

6. Devices: None discussed

7. Institutions:

a. Sponsor: United States Air Force
Wright Air Development Center, Air Research and Development Command, Wright- Patterson Air Force Base, OH 45433

b. Performing Organization:
American Institutes for Research Washington, DC

8. Type of Article: Theoretical/Methodological

9. Abstract: This 339-page book (of which the last 64 pages are bibliography and index) published in 1953, provides a detailed, comprehensive discussion of issues relevant to the design and use of training equipment. It is addressed principally to those who have already had some training in the psychology of human learning. An outline of the content, following the chapter headings listed in the book's Table of Contents, is as follows:

Section I. Human Learning - An Overview
a. General Adjustment to the Situation
b. Responses get Learned to Generalized Situation Cues
c. Localization of Responses
d. Verbal Mediation between Cue and Action
e. Context Learning: Response Inter-Association
f. The Importance of "Overlearning"

Section II. The Role of the Instructor in Training
a. Motivating Students
b. Explaining Principles, Relationships

The second program was the development of a Generalized Maintenance Trainging Simulator (GMTS) which was to be aimed at equipment familiarization, simulated practice, and testing on specific equipment associated with a particular class C school. The GMTS is a 2-dimensional CRT simulation with which the student interacts by means of a touch stylus. The GMTS was being programmed for use as a trainer-simulator for the WSC-3 Satellite Communications System, and four prototypes were about to be placed in the school for testing and evaluation.

The GMTS system embodies a single universal execution routine for simulating equipments, such that, when moving from one system simulation to another, only the data base, not the program, need be replaced. Subject-matter experts at schools are responsible for preparing the data base.

A typical troubleshooting problem is talked through to illustrate the use of the system.

Among the advantages cited for the GMTS is the ability to incorporate innovations in the equipment being simulated, simply by changing the data base.

The third program described was the Electro-mechanical Maintenance Training System Project, aimed at developing a family of simulation-trainers within the elctronics, electro- mechanical, and mechanical maintenance areas. Development and procurement of "Simulated Avionics Maintenance Trainers" (SAMTs) formed the nucleus of the project. Hardware development was still several months off at the time of this report.

1. Miller, Knox E.; Malec, Vernon M.

2. Title: Simulation in Maintenance Training

3. Source: unpublished Navy Personnel Research and Development Center Report, 1980

4. Topic Keywords: Maintenance Simulation ; Generalized Maintenance Trainer ; Electro-mechanical Maintenance Training ; Electronics Maintenance Training .

5. Short Summary: This report describes three maintenance training simulation research programs being conducted by the Naval Personnel Research and Development Center. The programs are discussed in the context of overall naval maintenance training objectives.

6. Devices: Generalized Maintenance Training Simulator

7. Institutions:

   a. Sponsor:
   Navy Personnel Research and Development Center, San Diego, CA 92152

   b. Performing Organization: same

8. Type of Article: Review

9. Abstract: This report describes three maintenance training simulation research programs being conducted by the Navy Personnel Research and Development Center. Two of these programs, aimed at distinctly different levels of electronics maintenance training, were well under way at the time of the report, with a device prototype approaching the testing stage in one of them. The third program, aimed at creating a common maintenance training data base, generic specifications, and an applications handbook, was in the intial planning stage.

The first program was the Electronics Equipment Maintenance Training (EEMT) System, which was "aimed at improving initial skills training at the Navy A school level." The design comprised one unit intended for use in basic skills training, and a second unit intended to provide hands-on experience. The first unit consisted of a CRT interactive display, an image projector, and a touch pen for student interactions, with a minicomputer at the heart of the system. The second unit would consist of digitally-controlled functional mock-ups of several drawers, each related to a family of equipment.

focus on the teaching of tasks rather than on physical realism of the simulator, and that departures from maximum fidelity are often desirable for two main reasons: (1) Realism and therefore cost can be reduced without impairing learning of the tasks; (2) addition of instructional features which may degrade fidelity can greatly enhance training.

The author concludes "optimal simulator design decisions should be based upon experimental evidence gathered from transfer of training studies. Once the relationship between training on a simulator and actual operational performance are understood, then knowledgeable decisions about simulator design can be made."

as training devices are cited from several sources; these are summarized as: (1) Provisions are made for active student participation; (2) there can be repeated practice on instructional segments; (3) instruction can be paced to the needs of the individual student; (4) the accuracy of student response can be confirmed; (5) the advantages of malfunction/emergency practice; (6) training equipment availability.

The issue of fidelity of simulation is discussed in respect to several views of fidelity dimensions and the basis for determining degree of fidelity required. A large number of empirical studies are cited in which inexpensive, low-fidelity trainers were found at least as effective in producing transfer of skills as far more expensive, high-fidelity counterparts. Nearly all these studies were confined to the domain of procedural tasks, however.

Planning for simulation should begin with a task analysis, of which several methods are available. Tasks can be classified according to various taxonomic schemes; the one advanced here, per Gagne and Bolles (1969), lists five chief categories: Procedures, Motor Skills, Indentifications, Conceptual Tasks, and Team Functions.

Stage of learning has a large impact on selection of training media, the use of simulation, and fidelity of simulation; the section dealing with this topic is the longest in the study. A general conclusion is, that the needed degree of fidelity rises as training progresses, and levels off at some point at a high level of skill.

The hypothetical relationship between fidelity, cost, and transfer of training proposed by Robert B. Miller in 1954 stands virtually unchallenged since "little hard scientific evidence has been collected to support or refute it." The Miller model postulates that transfer increases as fidelity (and therefore cost) increases, such that, for any particular stage of training, at first transfer rises rapidly while fidelity and cost rise slowly, then as higher fidelity is attained, cost rises rapidly while transfer rises slowly; at some "point of diminishing returns," optium cost- effectiveness is reached beyond which increasing fidelity becomes overcostly.

Principles of training are categorized according to three stages of learning (First, Middle, and High). These principles emphasize primarily how the simulator is used--e.g., repitition, feedback techniques, graduated loading, etc. The study ends with a section of "Transition Training," which propounds simulator design principles from several sources. These sources agree that design should

1. Author: Miller, Gary G.

2. Title: Some Considerations in the Design and Utilization of Simulators for Technical Training

3. Source: Technical Report: AFHRL-TR-74-65, August 1974, NTIS AD/A-001 630

4. Topic Keywords: Simulators ; Low Fidelity ; Training Devices ; Maintenance Training ; Cost-Effectiveness ; Training Effectiveness ; Task Analysis .

5. Short Summary: This paper reviews the current technical literature on simulations in training. It propounds rules and principles for cost-effective application of simulation, emphasizing the use of simple low-fidelity devices where appropriate, particularly in training procedural tasks.

6. Devices:

   a. SCI Console for Nike Hercules

   b. E-4 Fire Control System

   c. Tank Hull Trainer

   d. Simulated Maintenance Task Environment

7. Institutions:

   a. Sponsor: HQ Air Force Human Resources Laboratory (AFSC), Brooks AFB, TX 78235

   b. Performing Organization: Technical Training Division, Air Force Human Resources Laboratory, Lowry AFB, CO 80230

8. Type of article: Review

9. Abstract: This study reviews technical literature from 1954 to 1974, with a view to extracting general principles for the design and use of simulators in technical training (by which term the author means primarily maintenance training).

Definitions are discussed in which distinctions are made between "training aids" and "training equipment," and between "simulators" and "training devices." Two systems of classifying simulators by type are described.

Reasons for choosing simulators over operational equipment

9. Abstract: The purpose of this review was "to analyze the situation on the cost and training effectiveness of training devices" which was current at the time of the paper (1972).

A review was conducted of studies providing empirical data gathered in controlled experiments, and a summary made based on a commonality of findings. An appendix tabulating 19 "Early History" and 13 "Recent" studies identifies what equipment was simulated, what devices were studied, what skills were taught, and briefly describes the experiment and results. Both flying and non-flying tasks are included. The weight of evidence appears to support the use of simulators.

The experience of commercial airlines in adopting simulators for pilot training is adduced in favor of the use of simulators; a commercial airlines representative is cited as saying that "for the reason of cost, the airlines' objective is to perform 100% of training in simulators." Also, a representative of the USAF Human Research Laboratory is cited as saying that a 100% goal is "meaningful and viable." The author concludes, "as a result of this demonstration by the airlines of the feasibility and practicality of substitution of flight time by practice in training devices, the military should boldly adopt the policy of substitution for the appropriate portions of the flight training and other operational training syllabi."

A discussion of the need for fidelity concludes that "training effectiveness is more a matter of the manner in which the trainer is used than of the fidelity of the trainer." The author recommends minimizing simulator fidelity wherever possible in the interests of saving costs.

Roscoe's (1971) Transfer Effective Ratio and Caro's (1970) Equipment-Device Task Commonality Analysis are succinctly described in this paper.

1. Author: Micheli, Gene S.

2. Title: Analysis of the Transfer of Training, Substitution and Fidelity of Simulation of Training Equipment

3. Source: NAVTRAEQUIPCEN TAEG Report 2, 1972; NTIS No. AD-748 594

4. Topic Keywords: Transfer of Training ; Fidelity of Simulation ; Training Media Selection ; Training Effectiveness Prediction .

5. Short Summary: This paper reviews many empirical studies of the effectiveness of training devices and summarizes the commonality of findings. It concludes that training effectiveness depends more on how the trainer is used than on the fidelity of the trainer. It recommends the increased use of simulators for pilot training, not with the goal of exactly duplicating operational equipment, but with the goal of providing trainees with an opportunity to practice behaviors critical for their subsequent performance on operational equipment.

6. Devices:

Link AN-T-18 ; 12BK-1 Primary Landing Trainer ; C-3 Cycloramic Link Trainer ;
SJN Cycloramic (General) Link 1-CA-2 ; PBM-OFT ;
PB4Y-OFT ; 3-A-2 and 3-A-35 Aerial Gunnery Trainers ;
3-A-40 MK 18 Coordination Trainer ;
3-E-7 Ranging, Tracking Aiming Point Assessor ;
3-A-40b ; SNJ OFT ; NavBIT ; Aetna Drivo-trainer ;
Device 1BZ2 Maneuvering Tactics Trainer ;
15E18 Tactical ECM Trainer ; GAT-1 ;
X14A2 Surface Ship ASW Attack Trainer ; 2F66A Weapons System Trainer ;
21B20A Advanced Submerged Control Trainer ;
3A105 Tracked Vehicle Driving Trainer ; Carrier Air Traffic Control Center Trainer ; 2F69A (P-3A Weapon System Trainer) ;
2F90 (TA-4J Operational Flight Trainer) ; Whirlymite

7. Institutions:

a. Sponsor: Training Analysis and Evaluation Group, Naval Training Equipment Center, Orlando, FL 32813

b. Performing Organization: same

8. Type of Article: Review

training is based on two misconceptions: (1) failure to appreciate that all training is a compromise; (2) failure to understand that "the controlling factor is not physical congruence but the (sometimes subtle) cues that guide the behavior involved in the performance of a task."

Proper, through task analysis procedures are vital to the design of effective synthetic trainers.

R&D projects in Naval maintenance training are classified by the dimension of their "basic orientation or thrust". One group of projects emphasizes hardware; another emphasizes the development of integrated hardware/software/courseware; another focusses on a general purpose "universal" maintenance simulator--examples of the last are the Behavioral Technology Laboratory ("Rigney") system, and the Modular Integration of Training Information by a Performance Aiding Computer system.

Research models for single-rate and multi-rate maintenance training--the Hagan Automatic Boiler Control and Woodward Electronics Governor systems--are discussed; one conclusion from this research is that "it is apparent that the one functional skill for which hi-fidelity simulated practice is required is fault isolation."

A graduated learning sequence, represented by diagram, is described in a four-step schema: Knowledge Acquisition, Skill Acquisition, Integration, and Application, leading to On-the-Job training. The required fidelity of devices during this sequence progresses in general from low to high-- beginning with 2-dimensional displays and ending with operational equipment.

Future research plans are discussed at the end of the paper: one goal is to improve technology of instructional delivery, in particular overcoming weaknesses of the self- paced instructional mode.

1. Author: Malec, V. M.

2. Title: untitled

3. Source: unpublished; NPRDC 1980

4. Topic Keywords: Maintenance Training Simulation ; Behavioral Technology Laboratory System ; Modular Integration of Training Information ; Performance Aiding Computer ; General Purpose Simulator ; Fault Identification Simulator ; Unitary Instructional Systems .

5. Short Summary: Several programs of research and development in training of Naval maintenance personnel are discussed. An emphasis is placed on the advantages of simulator over actual equipment trainers, particularly in the early stages of skill training.

6. Devices:

   a. Hagan Automatic Boiler Control

   b. Woodward Electric Governor

   c. A7-HUD

   d. Simulated Avionic Maintenance Trainer

   e. Intermediate Hands-on Maintenance Simulator

7. Institutions:

   a. Naval Personnel Research and Development Center, San Diego, CA 92152

   b. Performing Organization: same

8. Type of Article: Review

9. Abstract: This study reviews ongoing Naval Research and Development projects in maintenance training, with an emphasis on the use of simulation rather than actual equipment devices for training, especially at the earlier stages of skill aquisition.

Practical drawbacks cited in the use of actual equipment for training are: (1) use of obsolescent equipment: (2) curtailment of practice for safety consideration; (3) high percentage of down-time.

Resistance to the application of simulators in maintenance

degrade transfer of training, although this may only be temporary." "There does not appear to be a strict requirement for high environment fidelity where easily perceived and interpreted information from the real world is provided on visual displays in the operational situation."

The required level of fidelity depends to some extent on the stage of learning. "Early in the training program (procedures training), the trainee cannot benefit from high degrees of either type of fidelity. However, as skill is acquired (familiarization training), there are requirements for increases in both environment and equipment fidelity ...."

Artifical knowledge of results, or feedback, can be used to advantage when stimulus conditions in the operational environment are clearly perceived; in other circumstances, performance in the transfer environment may suffer dramatically when artifical knowledge of results has been provided in training and is then withdrawn.

Designers should closely consider how the interaction between student and instructor is to take place, and avoid saddling the instructor with unreasonable demands.

briefly discussed. The bulk of this chapter, however, discusses training equipment, which is distinguished from training aids by the provision of active practice for the trainee.

Advantages and disadvantages of part-task vs. whole-task trainers are discussed. A simulator is defined as a part-task or whole-task trainer which (a) attempts to duplicate the essential features of a task situation, and (b) provides for direct practice. Simulator use is demanded when:

(1) It is less expensive than the actual equipment but still represents the essential task elements;
(2) it is the only feasible way to practice a task;
(3) it is more reliable for practice purposes than the actual equipment;
(4) it permits more effective control over the learning process than actual equipment.

Simulator use is usually appropriate in familiarization, skill, and transition training, but is less often appropriate for indoctrination or procedural training--in these initial phases, unsophisticated mock-ups having very low fidelity are usually adequate.

General principles of training device design are briefly described. The best overall design guideline for level of fidelity is "that (higher) fidelity of simulation is requried when the trainee must learn to make difficult discriminations between simulus events, and where the responses are either difficult to make or are highly critical to system operation."

Fidelity can be separated into three components:

(a) Equipment fidelity, the degree to which the simulator duplicates the appearance and "feel" of the operational equipment;
(b) Environmental fidelity, the degree to which the simulator duplicates the sensory stimulation (excluding control feel) which is received from the task situation;
(c) Psychological fidelity, the degree to which the simulator is perceived by the trainee as being a duplicate of the operational equipment and the task situation.

Psychological fidelity should be "achieved on the basis of perceptual limitations rather than on the basis of experimental limitations."

In regard to environmental fidelity, "gross deviations from the display of environmental factors may substantially

1. Authors: Kinkade, Robert G., & Wheaton, George R.

2. Title: Training Device Design

3. Source: Ch. 14 of Harold P. VanCoff & Robert G. Kincade (eds.), *Human Engineering Guide to Equipment Design*, Washington, DC, American Institutes for Research, 1972, pp. 667-699

4. Topic Keywords: Whole-task trainers ; Part-task trainers ; training aids ; equipment fidelity ; environment fidelity ; psychological fidelity ; scoring systems .

5. Short Summary: Design recommendations for training devices are given. The recommendations place the device within the context of the training system as a whole, and deal with concepts of fidelity and other design features which influence effectiveness of learning and efficiency f instruction.

6. Devices: None discussed

7. Institutions:

a. Sponsor: American Institutes for Research

b. Performing organization: American Institutes for Research, Washington, DC Office

8. Type of Article: Conceptual

9. Abstract: This chapter from VanCoff and Kinkade's Human Engineering Guide to Equipment Design (1972) places the design of training devices in the context of the training system as a whole, and discusses concepts of fidelity and other design features which influence effectiveness of student learning and efficiency of instruction.

Factors within the overall training system which bear on training device design are: training objectives, student population, practice procedures, the training program, other training devices, and evaluation requirements. The approach to design of the training device, rather than occurring in isolation, should weigh these factors heavily. For example, if the training objective does not include the acquisition of a high level of skill, the device probably need not provide high degrees of fidelity.

Training devices may be divided into two major classes: training aids and training equipment. Training aids, used by the instructor to help present subject matter, are

24 months of the inception of the programs.

Three principal reasons for success of the project are described in the report:

(a) It was the product of systematic application of instructional systems design methodology which integrated the synthetic training objectives, academic training objectives, and flight training objectives. The main features of the new programs included: (i) expanding the role of the instructor pilot to that of a training manager; (ii) individualized instruction through proficiency advancement techniques; (iii) crew or team training; (iv) functional context training; and (v) redesigning academic instruction... to emphasize how to operate the system rather than how the system operates.

(b) The Coast Guard employed an exemplary simulator procurement management system. A Project Officer, assigned to the project early, was kept at the same position throughout the procurement process. "All decisions made during the... process were oriented toward assuring that the simulators would be effective training devices, since the man making those decisions knew he was to be the user."

(c) "The project was much a cooperative venture between a military training agency and a training research contractor. It is HumRRO's view that it worked with, rather than for, the Coast Guard."

The text also briefly describes the simulator, designated the Variable Cockpit Training System. These devices proved effective training for the programs' objectives although they lacked an exterior visual simulation capability.

c. Providing the Student with a Criterion of Performance
d. Evaluating Student Performance
e. Communicating Evaluations and Directions to Students
f. Adjusting Degree of Task Difficulty
g. Adjusting to Individual Differences
h. Effecting Transition of Students to Self-Dependence
i. Operating the Training Device
j. Concluding Comments

Section III. The Trainer as a Demonstrator of Principles
a. Functions of Demonstration in Training
b. Selecting the Working Components of the Demonstration Trainer
c. Constructing the Trainer for Practicality
d. Concluding Comment

Section IV. The Use of Knowledge of Results
a. Introduction
b. Assumptions and Definitions
c. Informative Knowledge of Results: An Amplification
d. Operational versus Artificial Knowledge of Results
e. Training the Student in the Use of Learning Feedback
f. Interaction of Learning Feedback Information and the Student's Hypothesis of Cue or Response Relevancy
g. Time Values in Learning Feedback
h. Changes in Scoring Tolerences at Different Stages of Learning
i. Varying Emphasis on Student's Error Components
j. Changes in the Student's Selection and Use of Feedback

Section V. The Problem of Simulation
a. Introduction
b. Some Problems in the Man-Machine Error System
c. Stage of Learning and Degree of Simulation

Section VI. The Problem of Motivation
a. Definitions and General Statements
b. Social Group Differences in Incentives and Attitudes
c. Incentives in the Training Situation
d. Competition as a Motivational Influence
e.-l. (Other topics on motivation)

Section VII. Preparing the Specifications for a Training Device
a. Introduction
b. Stages Preliminary to Design Recommendations

c. Preparation of Specific Recommendations

Throughout, the book emphasizes the training of complex perceptual-psychomotor tasks. The author cites a lack of a "theory of learning which could be extended to cover the performance of highly complex skills by intelligent, symbol-using operators." The presentation is largely theoretical, bolstered at points by concrete, homely examples rather than by evidence from empirical studies (of which there were few available at the time with much validity). The author states that "these propositions must be offered as 'best guesses' in the making of decisions in training. It is hoped that psychologists will generally agree that they are 'best guesses.' It is also hoped that these guesses may be supported, modified, or refuted by certainties as research progresses."

The handbook's organization reflects three major problems in training: (1) "how to present... knowledge of results so as to maximize the benefits the student can get from the responses he has made in practice;" (2) "the problem of psychological simulation of tasks so that what is learned in one task environment will have positive transfer effects to another task environment;" (3) motivation.

A major portion of the book (110 pages) is devoted to the use of Knowledge of Results, which discusses learning as a problem in information processing. The 65-page section on "The Problem of Simulation" focusses primarily on the variation in simulation fidelity requirements (the terms "realism" or "similarity" are used in this book) as a function of stage of learning. The last section, on "Preparing the Specifications for a Training Device," highlights a proposed method based on task analysis.

A number of major points raised in the book relevant to transfer of training and the fidelity issue in training device design and use may be summarized as follows:

(a) Psychological similarity, not engineering similarity is the key to effective transfer of training.

(b) Transfer of learning from one environment to another depends on the context of the new task environment as well as specific stimuli. (This point is made in reference to transition training, but it applies to transfer from simulator to operational environment as well.)

(c) The requirements for engineering fidelity increase as the stage of learning progresses.

(d) "Overlearning" should not be used pejoratively. "Overlearning" a task to the point of eliminating medication between stimulus and response can be

extremely valuable.

(e) Physical differences between simulator and operational environment weigh heavily in instructor and student motivation. Management of the training program should work to instill positive attitudes toward training devices.

(f) "Decisions about phychological similarity or dissimilarity should not be based upon the 'analytical attitude' with respect to the physical stimulus. Other things being equal, proof of the similarity of two tasks, insofar as transfer value is concerned, has to be based on the transfer of training which can be obtained."

(g) As engineering fidelity increases, transfer of training (dependent on stage of learning) generally increases, up to a point of diminishing returns where very costly increases in engineering fidelity contribute little or nothing to training effectiveness. A graph used to illustrate this point has been subsequently employed by many other researchers in the field.

1. Author: Montague, William E.

2. Title: Is Simulation Fidelity the Question?

3. Source: U.S. Army Research Institute for the Behavioral and Social Sciences Technical Report 547, "Research Issues in the Determination of Simulator Fidelity: Proceedings of the ARI Sponsored Workshop 23-24 July 1981," November 1981; Robert T. Hays, editor, pp. 93-109

4. Topic Keywords: Simulation Fidelity ; Mental Models ; Transparency ; Analogical Correspondence .

5. Short Summary: The requirement for physical and stimulus fidelity is subordinate to the requirement for task fidelity, in the quest for training effectiveness.

6. Devices: None discussed

7. Institutions:

a. Sponsor: U.S. Army Research Institute for the Behavioral and Social Sciences, 5001 Eisenhower Avenue, Alexandria, VA 22333

b. Performing Organization: same

8. Type of Article: Theoretical

9. Abstract: The foundation of the author's approach is revealed in the following statements: "What is required for training simulators/devices is that they must provide the cues, the opportunities for trainees to respond, make and correct errors, and observe the consequences of their actions. Simulation that teaches well may violate the physical and temporal isomorphism, and its adequacy in training may be due to that fact. This idea is counterintuitive to the naive view that the most important design goal is to provide high physical and stimulus fidelity."

This paper attempts to identify guidelines for designing training devices that effectively teach the task, quite apart from questions of device fidelity. The following major goals of training devices/simulators are described: (a) "to build up in the learner's mind/memory a representation of the tasks to be performed and how the system functions; the goal is to build up the trainee's understanding of the system..." (b) "to produce smooth, error free, execution of needed procedures/responses"; (c) "to teach in a safe, less complicated environment, and perhaps show the consequences of unsafe actions"; (d) "to

provide for the development of skills"; (e) "to provide tutoring...that give hints, coaching, warnings, explanations."

Essential to effective training are the following characteristics of the training environment:

(a) The involvement of the learner

(b) An easily recognizable analogical correspondence between the simulation and the real task

(c) Opportunities to practice procedures frequently and to commit errors

(d) "Transparency", or clear knowledge of results.

None of the foregoing characteristics necessarily require high physical or stimulus fidelity.

Two principal concepts are central to a view of training which makes fidelity a secondary goal in designing a simulator and training program. First is that of the internal "mental model" which is used by the learner to understand the operational reality which is being simulated. This understanding might in many instances be brought about without a high degree of realism in simulation. The second concept is the necessity for task fidelity. A major problem in determining task fidelity is the lack of well-developed task analysis procedures, especially for complex tasks.

Naval sonar operator training devices and programs are used to illustrate some of these points.

1. Author: Montelermo, Melvin D.

2. Title: Training Device Design: The Simulation/Stimulation Controversy

3. Source: NAVTRAEQUIPCEN Technical Report IH-287, July 1977

4. Topic Keywords: Media Selection Models ; Training Devices ; Training Effectiveness ; Pierside Training .

5. Short Summary: This study develops a prototype model of the training device selection process. The model is based on seven factors pertinent to device effectiveness: cost, reliability, maintainability, safety, facility requirements, training features, and modifiability.

6. Devices: Many devices are mentioned in review

7. Institutions:

a. Sponsor: Commanding Officer, Naval Training Equipment Center, Orlando, FL 32813

b. Performing organization: Human Factors Laboratory, Naval Training Equipment Center, Orlando, FL 32813

8. Type of Article: Methodological

9. Abstract: This study sets forward what the author terms a "primitive model of the training device selection process." The model is constructed to guide choices between device options, which have in the past been guided largely by tradition.

It is noted that traditional selection policies in many branches of the service have favored actual equipment training devices, particularly in maintenance training, but that the acceptance of simulators has been gaining ground. Contradictory assertions from either side of the actual equipment versus simulator controversy are cited. The report proceeds to discuss, in reference to these options and with numerous specific examples, seven factors which constitute the proposed selection model: (1) reliability; (2) maintainability; (3) safety; (4) cost; (5) facility requirements; (6) training features; and (7) modifiability.

The author contends that consideration of these factors "should enable an experienced training technician to select and design traning devices which are more responsive to

training system requirements."

Whenever possible, the selection should be made by a team whose members combine expertise in instructional technology, engineering technology, the opertional equipment to be taught, and procurement procedures. The team's goals should be to:

a. involve the instructors who will be using the device;
b. develop a training program that capitalizes on the device's particular advantages;
c. develop a training program for instructors;
d. develop a training program to move the trainees from the device to the actual equipment;
e. ensure that the device is completely "debugged" before putting it into use;
f. prepare a maintenance program for the device;
g. prepare a modification program to ensure that the device is always kept up to date;
h. ensure that all team programs are adquately documented prior to disbanding.

The report also discusses recent developments in low-fidelity maintenance training simulators, though without discussing the fidelity issue per se.

In addition, a third training option, that of using actual equipment as a trainer, not in the schoolhouse but in a restricted field environment such as a ship at pierside--"Pierside Training"--is discussed with ten examples.

The author concludes by recommending further work to expand and refine the training media selection model; this work should focus on (1) other factors; (2) interaction among the factors; (3) relative importance of the factors; and (4) circumstances which affect the potency of each factor.

1. Author: National Technical Information Service

2. Title: Simulators in Education and Training, March 1980-June 1982

3. Source: U.S. Department of Commerce National Technical Information Service PB82-810953, August 1982; supersedes PB81-806622 and PB80-807787

4. Topic Keywords: Simulators ; Operations Training .

5. Short Summary: This bibliography references and abstracts 279 reports and journal articles in research on simulation and simulation technology, with the exception of flight simulators and flight simulation.

6. Devices: Various devices cited in 279 references

7. Institutions:

a. Sponsor: National Technical Information Service, Springfield, VA

b. Performing Organization: same

8. Type of Article: Review (Bibliography)

9. Abstract: The citations in this bibliography cover research on simulators and simulation technology in a broad range of educational and training settings. The earliest reference cited is April 1946 (a patent filing); the latest reference cited is from March 1982, with the great majority falling in the years 1979-1980. References are to studies of simulation in game playing and computer models, as well as military and commercial training.

Citations contain the minimum following information, where available: Title, Author(s), Corporate Author(s), Sponsoring Agency, Pages in Report, Report Date, Report Number, NTIS Subject Category, Keywords, Abstract of Content, NTIS Order Number, Microfiche Price Code, and Paper Copy Price Code.

Abstract length varies up to approximately 200 word (most are 100-150 words).

Approximately 18 of the references are patent filings for simulation devices. Approximately 14 deal with games. A breakdown by rough subject categories is as follows: Maintenance Training and Maintenance Training Devices: 25 citations; Operations Training (including War Games) and Operations Training Devices: 64 citations; Miscellaneous

1. Authors: Orlansky, J., & String, J.

2. Title: Cost-Effectiveness of Maintenance Simulators for Military Training

3. Source: IDA Paper P-1568, August 1981

4. Topic Keywords: Maintenance Simulation ; Cost-Effectiveness ; Fidelity of Simulation .

5. Short Summary: A review of research on maintenance training by simulation, accompanied by a cost-analysis of simulators, concludes, with some qualifications, that simulators are in general more cost-effective than actual equipment trainers.

6. Devices:

a. Generalized Sonar Maintenance Trainer

b. EC II , EC II VLP

c. Automated Electronics Maintenance Trainer

d. Generalized Maintenance Training System

e. Fault Identification Simulator (Hagen Automatic Boiler)

f. 6883 Convertor/Flight Control Systems Test Station

g. MA-3 Test Stand

h. Trident Integrated Radio Room

i. Trident High Pressure Air Compressor

j. Trident Air Conditioner

7. Institutions:

a. Sponsor: Office of the Under Secretary of Defense for Research and Engineering, The Pentagon, Washington, DC 20301

b. Performing Organization: Institute for Defense Analysis, 400 Army-Navy Drive, Arlington, VA 22202

8. Type of Article: Review

9. Abstract: This study evaluates the cost-effectiveness

of maintenance simulators versus actual equipment devices for training military maintenance technicians. The general conclusion, stated with slight qualification, is that simulators are more cost-effective than actual equipment for training. This conclusion is based on the following evidence gleaned from a review of empirical studies and a cost analysis:

a. Training Effectiveness, established via empirical studies:

(1) In 12 studies conducted since 1967, student achievement in 12 courses that used maintenance simulators was the same as or better than that in comparable courses that used actual equipment trainers; in one case, student achievement with a maintenance simulator was less.

(2) In the one case where on-the-job performance was evaluated, supervisors' ratings showed no difference between students trained with the simulator or an actual equipment trainer.

(3) In three cases where such data were collected, time savings (with the simulator) were 22, 50, and 50 percent.

(4) Most students who use maintenance simulators have favorable attitudes toward their use; instructors are split about equally in having favorable, neutral, or negative attitudes toward the use of these simulators.

b. Cost Analysis of Equipment, including 6 standard simulator systems or models, 17 non-standard systems, and one Computer-Aided-Instruction system, found:

(1) The cost to design, develop, and fabricate one unit of a simulator is less than 60 percent of the unit cost of its counterpart actual equipment trainer in 7 cases out of a sample of 11; in the remaining four cases the simulator cost more than the actual equipment trainers.

(2) Once developed, the cost of fabricating an additional unit of a simulator is less than 20 percent of the unit cost of its counterpart actual equipment trainer in 9 of those 11 cases; in only one case did the simulator cost more to fabricate than the actual equipment trainer.

(3) In the one available case of a life cycle cost- effectiveness evaluation; the simulator was as effective as the actual equipment trainers both at school and on the job. The total costs for the same student load over a 15 year period were estimated at between $1.5 million for the simulator and $3.9 million for the actual equipment trainer.

The conclusion as to cost-effectiveness of simulators is

qualified by three considerations: a limited number of valid comparisons are available; effectiveness has been measured by school rather than on-the-job performance in all but one case; and the cost analysis is based primarily on acquisition rather than life-cycle costs.

Additional research is required to clairfy several points. Especially, there is a need to determine how training methods affect later job performance. Furthermore, research could turn up more ways of increasing cost-effectiveness, particularly by modifying simulator fidelity: "the interrelationships of complexity, fidelity, and cost of training equipment and the transfer of training from training devices to operational equipment clearly deserve systematic attention."

1. Author: Payne, Thomas A.

2. Title: Conducting Studies of Transfer of Learning: A Practical Guide

3. Source: AFHRL-TR-81-25, January 1982

4. Topic Keywords: Transfer of training ; Transfer of learning ; Transfer effectiveness ratio ; Transfer performance measurement ; Flying training .

5. Short Summary: An outline of the methods of conducting a meaningful transfer of learning study makes a number of specific recommendations and cites examples from previous experiments, as well as constructing a general sequential framework consisting of eleven steps to be followed by researchers.

6. Devices: no specific devices

7. Institutions:

a. Sponsor: HQ Air Force Human Resources Laboratory (AFSC), Brooks AFB, TX 78235

b. Performing Organization: University of Dayton Research Institute, Dayton, OH 45469

8. Type of Article: Methodological

9. Abstract: This paper constitutes a guide primarily for conducting studies of transfer of learning from flight simulators to actual aircraft. A distinction is made between the term "transfer of learning" and the term "transfer of training" which is commonly equated with it, in order to clarify that it is the effect of training, not the process itself, that is the object of study.

Two methods for evaluation of transfer are presented, followed by eleven steps designed to furnish valid results for those models.

The two evaluative models are: (1) Percent Transfer of Learning, and (2) Transfer Effectiveness Ratio. The first expresses, as a percentage, the amount of real-aircraft training time that is saved by prior training in a simulator, or the graded performance increment that results from prior training in a simulator. The Transfer Effectiveness Ratio expresses the real aircraft training time saved as a fraction of the amount of prior simulator training time. The

latter model has the advantage of directly comparing the effectiveness of aircraft time with simulator time, thus offering a formula for computing cost-effectiveness.

The eleven steps identified as critical in conducting a transfer of learning study are as follows:
(1) Definition of the immediate problem--for example, the transitioning of pilots to a new type of aircraft
(2) Definition of the task
  (a) Phase of the curriculum
  (b) Specific sub-tasks
(3) Selection of subjects
  (a) Population to be represented
  (b) Matching versus random assignment to groups
(4) Performance Measurement Technique
  (a) Meaningful, logical relationship between measures and tasks
  (b) Establishment of performance criterion
  (c) Trials to criterion measure
  (d) Performance grading measures; "subjective" and "objective"
  (e) Practical significance
  (f) Recording techniques
  (g) Automated systems
(5) Instructors
  (a) Instructors train, not the device
  (b) Instructor as researcher
  (c) Instructor role in identifying simulator-to-aircraft differences
  (d) Adherence to study design
  (e) No instruction during measurement
  (f) Balance of instructors between groups, simulator and aircraft
(6) Planning for sufficient study time
(7) Avoidance of dilutant factors--e.g., time delays between blocks of training and transfer
(8) Scheduling in advance
(9) Operational Training Environment
(10) Testing the study method before taking final data
(11) Analysis of results
  (a) Interpretation of findings not to rest solely on probability (p) levels.
  (b) Inspect raw performance data first
  (c) Cross-comparisons of statistical test results with raw data
  (d) Undue concern with underlying assumptions of parametric tests.

Throughout this paper, heavy emphasis is placed on proper, thorough planning prior to the study, to include a preliminary study of possible experimental confounds, and

correctable equipment deficiencies. Another continuing concern of the researchers must be the adequacy of resources.

1. Author: Pitrella, F. D.

2. Title: Problems and Methods in Evaluating Force Steering and Other Flight Control Modes: A Study and an Experimental Design

3. Source: Forschungsinstitut fur Anthropotechnik Bericht Nr. 20 (Research Institute for Human Engineering Report No. 20), December 1974

4. Topic Keywords: Force steering ; Control wheel ; Flight control modes ; Instrument flight simulation ; Research simulation ; Fidelity .

5. Short Summary: Theoretical considerations and an experimental design are proposed for study of the flight-performance effectiveness of a partly automated aircraft flight control system, termed Force Steering, in a fixed-base instrument flight simulator.

6. Device: Instrument flight simulator with medium-high physical fidelity and medium-high functional fidelity

7. Institutions:

a. Sponsor: Forschungsinstitut fur Anthropotechnik, Luftelberger Strasse L 1123, 5309 Meckenheim, Germany

b. Performing organization: same

8. Type of Article: Theoretical/Methodological

9. Abstract: Force steering, a flight control system which seeks to optimize the interaction between the human pilot and the automated pilot, had theoretical advantages over the manual and automatic piloting systems in use at the time of this study, but these had not been experimentally proved. The objective of the research proposed in this paper was to study the effectiveness of Force Steering in instrument approach and landing of the aircraft, in comparison with (1) fully automated approach control; (2) semi-automatic control; and (3) fully manual control.

Force Steering is a compound control mode which includes three types of control signals in various combinations depending on pilot decision. It enables the pilot to participate in the system at different levels of the aircraft control hierarchy, rather than being compelled to choose between submitting to the Flight Director, or taking over complete control. Fundamental to the Force Steering design is the concept that machines are more suitable for performing lower-level functions such as changing the rudder

to maintain a selected glidepath, while humans are better at higher level functions such as determining the glidepath.

It was proposed to evaluate the Force Steering model by determining the relative contributions of the four modes. This was to be done in a fixed-base simulator in three ways: (1) by directly comparing landing approach performing differences among the four control modes; (2) by measuring and recording the percentage of time that Force Steering is characterized predominately by each of the contributory modes; (3) by measuring and recording the percentage of time that a pilot makes control inputs and the force magnitude of those inputs.

In order to discriminate between the influences of status displays and Flight Director displays on the pilot, the experiment was to use three different display configurations: (1) conventional panel without the display of Flight Director information (information restricted to status error displays); (2) conventional panel with both Flight Director and status error information displayed (3) conventional panel with Flight Director information but without status error information.

Experimental hypotheses were advanced on the following: (1) normal condition landing; (2) turbulent condition landing; (3) automaticity levels during differing conditions.

Discription of Proposed Experiment:

a. Number of groups: 3 or 4

b. Description of groups: to be selected from 12-18 minimum, pilots with small or moderate-size jet experience or training with instrument landing approach

c. Test or trials/timing: in-process trials

d. Number of different types of measures: 2

e. Description of measurements and ratings: objective quantitative measurements of (1) flightpath errors, deviations; and (2) control inputs

f. Experimental setting/training context: Laboratory, hands-on

g. Statistical methods: 3x3 factorial ANOVA; Tukey's test of nonadditivity

h. Variables being manipulated:

- (1) Training device: as above, section 6
  - (a) Force steering modes
  - (b) Fully automatic modes
  - (c) Semi-automatic mode
  - (d) Fully manual mode
- (2) Fidelity Levels:
  - (a) Physical: Medium-high
  - (b) Functional: Medium-high
- (3) Type of task/skill required: operations,

cognitive, psychomotor, perceptual, part-task
(4) Task difficulty: High
i. Stage of training: skill (experimental only)
j. Trainee sophistication: intermediate
k. Incorporation of device into P.O.I.: lock-step
l. User acceptance or attitude: not applicable
m. Use of instructional features:
(1) Intensity: assumed will be intensive
(2) Features used: not specified

The degree and fidelity of simulator realism required to produce valid results was discussed. It was proposed that a submaximal degree of realism could achieve the desired level of validity, because the research goals were not to demonstrate precisely what would happen in the real world, but rather to obtain a relative rank order of performance among the four control modes under study. In no case was the principle of realism to interfere with the requirements of achieving good experimental control.

Other issues discussed were: the performance measurement problem; the question of task difficulty; the selection of an adaptive variable as the primary dependent variable; assymetrical transfer of training; experimenter bias and control technique bais; performance and adaptive measurement instability with angular information; adequacy of data sampling and matching; and other experimental control issues.

1. Authors: Purifoy, George R. Jr., & Benson, Eugene W.

2. Title: Maintenance Training Simulators Design and Acquisition: Summary of Current Procedures

3. Source: AFHRL-TR-79-23, November 1979

4. Topic Keywords: Maintenance Training Simulation ; Instructional Systems Development ; Computer-assisted instruction .

5. Short Summary: This paper describes administrative procedures involved in the design and acquisition of maintenance training simulators. Both the Instructional Systems Development (ISD) procedures and the system Program Office (SPO) procedures are discussed.

6. Devices: None discussed

7. Institutions:

a. Sponsor: HQ Air Force Human Resources Laboratory (AFSC), Brooks AFB, TX 78235

b. Performing Organization:
Applied Science Associates, Inc., Box 158, Valencia, PA 16059

8. Type of article: Theoretical

9. Abstract: This paper is the first in a series exploring the problems of maintenance training simulator design and acquisition. It focusses on the administrative procedures in the decision-making process and has only cursory relevance to the training issues that are involved in the design of devices and programs of instruction. It does illustrate, however, how the training issues are embedded in the large organizational activity of device development and acquisition.

Th design and procurement activity is broken down into three major phases: (1) identification of requirements; (2) development of specifications; and (3) procurement. A design process model is described to assist in the identification of requirements and development of specifications. The purpose of this design model is to lay the groundwork for forthcoming hierarchical and associative relationships between information about tasks and appropriate training equipment characteristics and training applications by comparing it to currently used procedure.

The decision sequence of the model is as follows:

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(1) Determine job-relevant skills and knowledge;
(2) Specify skills and knowledge which must be learned;
(3) Identify skills and knowledge best learned on equipment;
(4) Group skills and knowledge by training equipment class;
(5) Specify how well training equipment related skills and knowledge must be learned;
(6) Sequence all training requirements;
(7) Establish training equipment design concepts;
(8) Development a preliminary plan of instruction;
(9) Finalize functional equipment characteristics;
(10) Document training equipment design.

A key to the selection of design features and instructional program is the concept that for any set of tasks to be trained, there are a number of alternative combinations of training media which can be employed to successfully achieve required learning.

1. Authors: Rolfe, J. M., & Waag, Wayne L.

2. Title: Fidelity of Flight Simulation for Pilot Training

3. Source: Royal Air Force Education Bulletin No. 18, Autumn 1980

4. Topic Keywords: Fidelity of Simulation ; Flight Simulation ; Cost-Effectiveness Ratio .

5. Short Summary: Alternatives to designing training devices for maximum fidelity are discussed, with a focus on cost-effective means for accomplishing specific training objectives.

6. Devices: None discussed

7. Institutions:

   a. Sponsor: Royal Air Force Support Command, Upwood, England

   b. Performing Organization: same

8. Type of Article: Theoretical

9. Abstract: This study is based on the premise that cost-effective training by simulation is seldom achieved through the uncritical adoption of the "fidelity model" of simulator design which assumes that the more realism in the simulator, the better for training. Three practical considerations underlie this premise: (1) the high cost of achieving high simulator fidelity; (2) the fact that the ultimate in realism is unattainable in a simulator by definition; and (3) research data indicate that effective training can be achieved without high fidelity of simulation, in many cases.

The study outlines, with the help of a block diagram, methods for selecting the training media, and determining the fidelity requirements for those media, within the context of the training system as a whole. The key to selection of appropriate training device design features is the clear specification of training objectives, which pivots on a mission analysis of the constellation of tasks to be learned by the aircrew.

Principles of simulator training which have been established by research are:

(1) "The flight simulator is an effective means of teaching and maintaining aircrew skills."

(2) "Substantial amounts of time in the air can be replaced by the use of simulators."

(3) "The ease with which tasks can be learned... and transferred... varies with the nature of the task.... Procedural skills will transfer readily but will be forgotten unless practiced regularly. Perceptual motor skills transfer less completely...."
(4) "The effects of simulator training are most apparent in the critical period immediately after the student moves... to aircraft."
(5) "Training effectiveness is not determined solely by the appropriateness of the training device to the ... task. How the device is used can influence its effectiveness to an equal or greater extent."
(6) "Training effectiveness can be improved by reducing the level of complexity in the training device.... (Also)... changes to the equipment may be necessary in order to facilitate feedback... and to allow the manipulation of the training task."
(7) "Motivation is a key element in achieving effective training in a ground trainer."
(8) "The degree of realism of simulation required will depend on the nature of the task, the level of experience of the students, and the level of (expcted) proficiency...."
(9) "Visual tasks learned in the simulator show positive transfer to the aircraft.... Few studies have been accomplished for tasks other than transition...."
(10) "There is insufficient research data to make conclusive statements regarding the value of motion in the training context."

The authors conclude that "the research data base regarding the requirements for effective training is quite limited."

A Cost Effectiveness Ratio, which is derived from dividing the Transfer Effectiveness Ratio by the Training Cost Ratio, is discussed and illustrated by two examples from Royal Air Force flight training programs. The Transfer of Training model for evaluating simulator training effectiveness is discussed and its limitations pointed out--particularly the inconstancy, in most experiments, of how the simulator is used.

1. Authors: Roscoe, Stanley N., & Ozkaptan, Halim

2. Title: Review of Flight Training Technology

3. Source: U.S. A.R.I. Research Problem Review 76-3, July 1976

4. Topic Keywords: Helicopter Flight Simulation ; Nap-of-the-Earth Aircrew Training ; Residual Attention ; Automatically Adaptive Training ; Computer-Assisted Instruction .

5. Snort Summary: A survey of possible options for simulator designs appropriate for Nap-of-the-Earch helicopter flight training suggests part-task simulated training, using cinematic methods, combined with air training, as the most effective solution.

6. Devices: 2-B-24 Synthetic Flight Training System (mentioned)

7. Institutions:

a. Sponsor: U.S. Army Research Institute for the Behavioral and Social Sciences, Alexandria, VA 22333

b. Performing Organization: Anacapa Sciences, Incorporated,
University of Illinois Institute of Aviation

8. Type of Article: Review

9. Abstract: The purpose of this report was to review the state of the art of aircrew training technology, particularly in simulation, as part of a program to identify areas in which nap-of-the-earth (NOE) aircrew training might be most readily improved.

The principal limitation in applying simulation to training NOE helicopter flight--which involves below-treetop- level maneuvers--is the extreme comlexity of the visual environment. Flight simulators at the time of the report could not provide closed-loop capacity for this kind of flight--that is, in a way where the pilot could control the simulated motion of the aircraft. The alternative recommended is the combination of cinematic simulation--the use of films taken in real flight--with air training. Open-loop film presentations, which can permit closed-loop control of pitch, yaw, roll, and speed, but not of the three translational degrees of freedom, have been used successfully in training high-speed, low altitude navigation and have promise for NOE flight training.

A number of other topics are discussed in addition to that of outside-cockpit visual simulation. Heavy stress is placed on attaining the highest possible procedural fidelity. Procedural skills are more aircraft-specific and more easily forgotten than perceptual-motor skills. Other topics which are discussed come under the general heading of "innovations in flight training": Automatically Adaptive Training; Computer-Assisted Instruction, Adaptive Measurement of Residual Attention, Automatic Performance Measurement, and Interactive Computer-Control-Display Devices. Of these, only Computer-Assisted Instruction (CAI) and Adaptive Measurement of Residual Attention are strongly recommended for the NOE flight appliction. Standardization of instruction and individually paced instruction are advantages of CAI. Measurement of Residual Attention serves to discriminate among ability of pilots and to assess their readiness to cope with the stress of combat or equipment malfunction.

A concise discussion of automated performance measurement emphasizes it is not instrumentation which is the problem, but rather detemining what characteristics to measure, and what kind of parameters furnish the most useful data.

1. Author: Semple, Clarence A.

2. Title: Guidelines for Implementing Training Effectiveness Evaluations

3. Source: Technical Report, NAVTRAEQUIPCEN 72-C-0209-3; NTIS AD-778 349, April 1974

4. Topic Keywords: Training Effectiveness Evaluation ; Human Factors .

5. Short Summary: This paper presents guidelines for planning, implementing, and documenting training effectiveness evaluations.

6. Devices: None discussed

7. Institutions:

a. Sponsor: Naval Training Equipment Center, Orlando, FL 32813

b. Performing Organization:
Manned Systems Sciences Inc., 8949 Reseda Blvd., Suite 206, Northridge, CA 91324

8. Type of Article: Theoretical

9. Abstract: The training effectiveness evaluation is employed to determine the effects on training of a modification in an ongoing program. The rationale for performing evaluations is that "training personnel need such estimates to be able to project skill and knowledge levels which will result from modified training, determine cost effectiveness of training, husband all training resources, and identify areas where further modifications may be desirable." This report deals with three major considerations in evaluation:

(1) The evaluation process should have the least possible impact on the program under evaluation, both to avoid altering the training itself, and to earn the good will and cooperation of training personnel.

(2) There are alternative models of evaluation of which the transfer of training experiment is only one. Selection among the alternatives constitutes a major initial planning step.

(3) The evaluation must be geared not merely to obtain reliable meaningful, and practical information, but to obtain reliable, meaningful, and practical information.

Concerning impact on the training program, it is vital that the evaluation personnel adopt a guest relationship to the

host training program personnel. The evaluation should be planned and conducted on a "not to interefere" basis.

Concerning choices of evaluative model or models, it must be understood that "there are alternative models which are applicable to training effectiveness evaluations... The further one regresses from the classic transfer of training model, the less concrete, defensible and generalizable the resulting information becomes." Four levels of evaluation are outlined in a table for quick reference.

Obtaining reliable, meaningful and practical information depends not only on techniques of information gathering but upon orienting the evaluation to clearly specified goals of the training program. "Achieving agreed upon definitions of why training modifications are being made... is a cornerstone of a useful training effectiveness evaluation."

General recommendations for dealing with management problems--especially lead-time planning problems--and specific measurement, analysis, and documentation techniques are discussed.

1. Author: Semple, Clarence A.

2. Title: Executive Summary: A Report of the Simulator Training Requirements and Effectiveness Study (STRES)

3. Source: Technical Report, AFHRL-TR-80-63, July 1980; NTIS No. AD-A094 381

4. Topic Keywords: Flight simulation ; Life Cycle cost ; Aircrew training devices ; Training effectiveness ; Cost Modeling ; Fidelity ; Instructional Support Features ; Worth of Ownership ; Transfer of- Training .

5. Short Summary: This review summarizes the contents of six reports on aircrew training devices performed as part of the Simulator Training Requirements and Effectiveness Study (STRES), and indexes these technical reports.

6. Devices: None discussed

7. Institutions:

a. Sponsor: Air Force Human Resources Laboratory , Advanced Systems Division, Wright-Patterson AFB, OH 45433

b. Performing Organization: Canyon Research Group, Inc. , 741 Lakefield Rd., Suite B, Westlake Village, CA 91361

8. Type of Article: Review

9. Abstract: The purposes of this report were (1) to summarize the content of six other technical reports prepared during the Simulator Training Requirements and Effectiveness Study (STRES), and (2) to provide a master index to the content of program technical reports dealing with the design, use, life cycle cost and worth of ownership of aircrew training devices. The basic goals of the STRES study include: (1) to develop criteria to match training requirements to simulator features; (2) to define principles for effective use of aircrew training devices; (3) to develop principles for matching instructional features to training requirements; and (4) to accumulate data on cost-effectiveness of aircrew training devices.

The following issues are addressed in the studies which are summarized: aircrew training device fidelity; instructional support features, utilization of training devices in aircrew training programs; training device life cycle costs; and worth of ownership.

1. Author: Spangenberg, Ronald W.

2. Title: Selection of Simulation as an Instructional Medium

3. Source: First International Learning Technology Society & Exposition on Applied Learning Technology, Society for Applied Learning Technology, 21-23 July 1965, Proceedings Vol. IV: "Future of Simulators in Skills Training", pp. 65.

4. Topic Keywords: Simulation ; Instructional Media Selection .

5. Short Summary: This paper briefly describes seven advantages of simulation as a training medium and advocates the case study approach as a means of establishing a predictive body of knowledge about simulator training effectiveness and, ultimately, improving planning and design of simulations.

6. Devices: None discussed

7. Institutions:

a. Sponsor: Society for Applied Learning Technology

b. Performing Organization: Air Force Human Resources Laboratory

8. Type of Article: Theoretical

9. Abstract: This paper briefly describes the advantages of simulation as a training medium and advocates the case study approach as a means to improving the planning and design of simulations.

In the selection of simulation as a training medium, it should be borne in mind that tasks with "abstract information inputs requiring the production of abstractions are less likely to require that the training task environment resemble the actual task environment"--i.e., simulators of high realism are more appropriate to the learning of concrete tasks.

Seven unique advantages of simulation are cited:

(a) Can provide extra knowledge of results (feedback)
(b) Can increase the number and frequency of problems to be practiced
(c) Can compress time
(d) Can vary the sequence of tasks
(e) Can provide guidance and stimulus support

from maximum fidelity (e.g., display enhancement, augmented feedback) in order to increase the instructional efficiency of the device. Flexibility is also a key issue, in that design options must be capable of handling potential revision, or addition of training objectives.

Determination of fidelity rests on two considerations: what or how much to simulate, and how realistically to simulate it. "In principle, the design criterion is clear: it provides the minimum fidelity of simulation needed to develop and exercise the human performances required in the operational environment." Four basic levels of fidelity are identified: (1) High-Fidelity Representation; (2) Deliberate Reduction in Fidelity Where the Engineering State-of-the-Art is Adequate; (3) Reduction in Fidelity Tolerances when the Engineering State-of-the-Art is Less than Adequate; (4) Deliberate Departures from Realism.

Deliberate reductions in fidelity can be assessed from a negative standpoint--that is, in the interests of reducing costs, how much fidelity can be sacrificed without significantly reducing trainee performance. Fidelity reduction resulting from limitations in engineering capability are more problematical: "the solutions are less than desired, and design practices... rely more on empirical determinations since precise quantitative design information is lacking." On the other hand, deliberate departures from realism calculated to enhance training effectiveness reflect the incorporation of training technology into design practices.

1. Authors: Smode, Alfred F., & Hall, Eugene R.

2. Title: Translating Information Requirements into Training Device Fidelity Requirements

3. Source: Proceedings of the Human Factors Society , 19th Annual Meeting, Dallas, TX, October 14-16, 1975, pp. 33-39

4. Topic Keywords: Simulation ; Fidelity ; Training Effectiveness ; Front end analysis .

5. Short Summary: Observations on issues in training device fidelity support the view that inaccurate or inadequate information may be equally at fault with inadequate engineering fidelity when equipment fails to fulfill training needs. A more solid information base on the human factors involved in training is necessary to adequately determine device fidelity requirements.

6. Devices: None discussed

7. Institutions:

   a. Sponsor: Training Analysis and Evaluation Group, U.S. Navy, Orlando FL 32813

   b. Performing Organization: same

8. Type of Article: Review

9. Abstract: Flaws in training device design are not due solely to lack of engineering fidelity. In fact, reduced-fidelity devices have been shown in many cases equally as, or more effective, than high-fidelity devices in training for the same task. Just as important as engineering fidelity to device design is the application of human learning factors.

"The development of device training requirements... is a deceptively complex process, not fully understood." Analyses of tasks to be learned must include not only the operational performance itself, but also the stimulus configurations which cue the action, and influential environmental factors. Selection of sub-tasks to be learned is a "complex iterative process requiring multiple trade-offs." Much of the training inadequacies of simulators are due to imprecision or errors in information derived from these analyses.

Translation of training requirements into device design involves the specification of what functions the equipment is to perform and detailed design prescriptions to produce these functions. This may involve deliberate deviations

Trainee Station Design, in relation to cost-effectiveness, hinges on the questions of what task elements are to simulated, and what degree of fidelity is required for those elements selected. "Of concern is the extent to which certain events must be simulated and their relative importance and criticality for training."

Four levels of fidelity are identified: (1) High Fidelity (engineering state-of-the-art is adequate; (2) Fidelity achievable where reduction in tolerances is required (engineering state-of-the-art is less than adequate); (3) Simulate generalized functions; and (4) deliberate departures from realism (qualitative deviations from the operational system being simulated). Deliberate reductions of fidelity, or departures from realism, which are not the result of engineering limitations, have either of two distinct purposes: either to save costs without lowering training effectiveness, or to introduce non-realistic features, such as display enhancement, which increase the training capability or flexibility of the device.

Instructor Station Design. Two desiderata dominate this design area: (1) automating key instructor functions; and (2) generalized, modular construction. These two features can increase flexibility and economy in design and enable "substantial modifications in instructional capability within a given device or across similar devices without radical change in instructor station configuration."

Requirements for the instructor station fall into two principal domains: (1) information requirements; and (2) control requirements. The instructor must have means both to manipulate the simulated conditions and to monitor and evaluate the student's performance. Fourteen chapters in this section describe the requirements pertinent to the structure and control of training during off-line, pre-mission, enroute training, and post-exercise operations.

A detailed list of instructor functions is provided, which identifies for each function its place in the total training sequence, and the station capability and instructor involvement. An instructor functions flow analysis and checklist of information requirements are also provided.

Evaluation of Design: This section describes the techniques for evaluating the design in three principal steps: (1) Mock-Up Evaluation; (2) Static and Part-System Verification Testing; and (3) Instuctional Suitability Testing. The role of supporting research is also discussed.

1. Author: Smode, Alfred F.

2. Title: Training Device Design: Human Factors Requirements in the Technical Approach

3. Source: NAVTRAEQUIPCEN Technical Report 71-C-0013-1, August 1972

4. Topic Keywords: Simulation Fidelity ; Human Factors ; Instructor Station ; Performance Measures .

5. Short Summary: This document, primarily a handbook of techniques and procedures, presents guidelines for applying human factors knowledge to the design of training devices, and describes a method for correlating instructional requirements with engineering design alternatives.

6. Devices:

   a. A7E Operational Flight Trainer, Device 2F100

   b. Synthetic Flight Training System, Device 2B24

   c. Device 1D23 Air Navigation Trainer

7. Institutions:

   a. Sponsor: Naval Training Equipment Center, Orlando, FL 32813

   b. Performing Organization: same

8. Type of Article: Methodological

9. Abstract: This document presents guidelines for applying human factors knowledge to the design of training devices. It is primarily a handbook of techniques and procedures, and provides little conceptual information. The techniques and procedures described assist the process of the "Technical Approach" which links the initial documentation and description of training need, with the engineering of the device. Execution of these procedures prior to the exploration of engineering options should help ensure that technical considerations are subordinated to human factors considerations. Emphasis is on the instructional capability of the device, and nearly two-thirds of the material deals with the design of the instructor station.

Three major areas are dealt with separately: (1) Training Station Design; (2) Instructor Station Design; and (3) Evaluation of Design.

definition of adaptive variables and difficulties in the measurement of performance.

(7) Deliberate Departure from Realism in Design. This section presents concepts and techniques for deliberately departing from realism in design in order to enhance training effectiveness. Topics are: augmented information feedback, display enhancement, guidance supports, and mediation.

(a) Augmenting information feedback, in terms of rapidity, variety, and supplementation, has been shown to increase speed of learning acquisition. Studies of transfer are not discussed here.

(b) Display enhancement provides for the enhancing of signals to ensure detection and identification in cluttered displays.

(c) Guidance support, or cue-prompting, has been shown useful in acquisition of part-task learning. The experimental evidence is still rather slim, and ambiguous. Studies of transfer are not discussed here.

(d) Mediation involves selection non-equipment options as part of the device. This approach reduces or simplifies hardware and employs the instructor in the training loop. Examples of this technique are cited without citing experimental evidence.

d. Demonstration of Principles in Design of a Specific Trainer: This section illustrates the application of the prescribed methodology to the design of an actual device. This reconstruction is based for the most part on analyses made by Dunlap & Associates in the development of a short-based team trainer for destroyer and cruiser ASW operations.

lags, stimulus-response compatibility and vigilance.

Design techniques for enhancing displays for training are discussed. Topics are: information coding, and actual versus simulated targets.

(5) Measurement System Design. In this section, "emphasis is placed on automatic human performance monitoring and recording means for providing measures and scores that can be organized, manipulated and applied to achieve the purposes of assessment." Current training devices are generally deficient in well-developed measurement capability. Instructor scoring is the norm. The measurement weakness results from designing for simulator fidelity with little concern for measurement. Measures are often not closely linked with transfer proficiency, and the difficulty of measurement often dictates the practice of measuring what is easily measurable rather than what is of practical significance. Little commonality exists between measurement for training and measurement for system test and development. Measurement of tactical decision-making is especially problematic because rarely are absolute right or wrong choices made. Also, the measurement of team performance is difficult. Means for quantifying behavioral elements must be established before consistently valid measurements can be taken.

(6) Adaptive Training Strategies. As considered here, adaptive training is restricted to computer-controlled automation of the instructor function in a closed-loop feed-back system, where task difficulty is progressively changed to match the trainee's level of skill. Variations in conceptualization of adaptive training are described, with the two principal themes being: (a) assistance from the computer via display augmentation is adjusted as a results of the subject's instantaneous performance; (b) an average of the subject's error, or "continuously distributed error", is compared with an error threshhold to make the system either easier or more difficult.

No empirical evidence existed at the time of this report's publication to confirm the effectiveness of adaptive training techniques in simulator training. However, many theoretical advantages inhere in adaptive training which make some features of it intuitively desirable.

The remainder of this section explores problems associated with the conceptualization and

precise in sensing movement as the motion senses." However, it is acknowledged that "evidence supporting the decision to incorporate motion into the ground-based trainer is yet incomplete in terms of actual transfer benefits; the majority of the findings do not yield clear expressions of the extent of transfer of training."

The remainder of this section covers priorities of motion requirements, according to kind of motion and task, sensory threshholds for motion perception, achieving acceleration cues in simulation, acceleration onset and washout, scaling of motion forces, differential pressures on the body as motion cues, shearing forces, some specifications for achieving motion, visual motion interaction, and vibration.

(3) Vehicle Control Requirements. "Assuming cost minimization as a goal, design and fabrication costs may be reduced by subtracting unneeded simulator fidelity from a contemplated design."

Topics covered in this section are:

(a) the purpose of simulator controls (as distinct from aircraft controls);
(b) desired control fidelity;
(c) evaluative criteria for simulator controls;
(d) research issues.

In regard to fidelity, the practical questions, both of cost and of the benefits of features which lower fidelity while enhancing training versatility (e.g., augmented feedback), are addressed. The following issues in simulation fidelity are discusses; motivational benefits of realism; fidelity of configuration; requirements for interactive tasks; simplification of aerodynamic equations; program cycle time; control types, and effective time constant.

(4) Information Processing. "Viewing man as a single- channel limited transmission capacity information processing system provides the potential for specifying system components most compatible with his capabilities."

Types of information processing tasks are identified: conservation of information tasks, information filtering tasks, and information condensing tasks. The human information handling capacity is described. Variables affecting the perceiving and processing of information are identified: detecting and discriminating visual signals, amount and distribution of input information, distortions in input information, the influence of noise, signal intermittency, time

training simulators, and field contexts, and generalizes the findings of the issues in device design. Seven topics are investigated, and summarized in order below:

(1) Visual Simulation. Effective visual simulation in training does not depend on achieving a one-to-one copy. The challenge is to meet task fidelity requirements.

Visual characteristics are identified as follows: size of field, size of objects, luminance of objects and background, shape of objects, color of objects and background, distance of objects in the field, motion of objects, variations in brightness. These characteristics are discussed in detail, with regard to their role in simulation.

A technique is described for developing visual simulation specifications. Advantages and disadvantages of various visual simulation media are itemized. "... The most important aspect of this analytic technique is that it deals explicitly with those factors which are important in the selection of simulation hardware but which are not recognized as quantitative system parameters." To illustrate, the technique is applied to three candidate simulation technologies--CCTV-model, wide-angle open-loop movie, and computer-based imagery--as a function of the same set of simulation requirements.

(2) Platform Motion Simulation. This section emphasizes acceleration and deceleration force magnitudes. A number of issues of prime concern in the aerospace environment are minimally important to training simulator design, primarily those dealing with physiological reaction to acceleration stresses.

Findings from a number of studies are adduced to support the case for the contribution of simulated platform motion to improved student pilot performance in the simulator. Especially in the case of simulated flight under heavy turbulence conditions, "motion aids in the building of a response pattern which transfers positively to the aircraft.

The importance of motion cues appears to be a function of the experience level of the pilot, but whether motion in ths simulator is more important for initial skill acquisition or for training pilots of some experience will depend upon the task, among other things.

The argument in favor of motion is based primarily on the contention that "the visual sense is not as

(2) Design coordinates two distinct but closely interrelated functions:

(a) trainer station design, which focuses on achieving fidelity of simulation;

(b) the management of training, focussing on structure, control, monitoring, and recording of training;

(3) Limitations on design options are:

(a) the methods for achieving human factors design solutions are inexact;

(b) the information base of concepts and data pertinent to design is weak;

(c) considerable gaps in design data exist and some information has marginal value.

(4) International sacrifices of physical fidelity or operational realism can be made in the device which either do not detract from, or actually increase, the training effectiveness of the device (e.g., signal enhancement);

(5) The most efficient selection of degree of fidelity should be based on perceptual equivalence to the operational environment;

(6) Long-term costs of device modification may weigh against seeking initial cost savings which inhibit the flexibility of the device; computer advances may make it counter-productive to skimp on high fidelity.

b. Methodology: This section describes the roughly chronological sequence of the following steps in design development:

(1) Definition of the purpose of the training system;

(2) Analysis of the operational system;

(3) Analysis of tasks involving the trainee(s):

(a) task structure;

(b) training objectives;

(c) identification of simulation elements relative to own-vehicle characteristics, target characteristics, and the media.

(4) Gross device hardware definition;

(5) Definition of the characteristics of the operational environment to simulate for training;

(6) Representing the operational environment in the trainee compartment(s);

(7) Provisions for the management of training at the instructor station (design for the structure and control of training).

Extensive classification of simulation elements, and of measures, are included in this section.

c. Applicable Concepts and Date: This section examines the literature of studies in the laboratory,

1. Author: Smode, Alfred F.

2. Title: Human Factors Inputs to the Training Device Design Process

3. Source: NAVTRADEVCEN Technical Report 69-C-0298-1, September 1971

4. Topic Keywords: Transfer of Training ; Measurement Systems ; Augmented Feedback ; Platform Motion ; Adaptive Training ; Fidelity ; Flight Simulation ; Cue Prompting ; Human Factors ; Training Effectiveness .

5. Short Summary: A comprehensive catalog is made of methods and issues relevant to human factors in the design of training devices (simulators), with reference to pertinent research and learning concepts.

6. Devices: Device 14A2, ASROC/ASW Early Attack Warning System Trainer is discussed at length as an example.

7. Institutions:

   a. Sponsor: Human Factors Laboratory, Naval Training Device Center, Orlando, FL 32813

   b. Performing Organization: Dunlap and Associates , Inc., Darien, CT 60820

8. Type of Article: Review/Theoretical

9. Abstract:

   a. Introduction: This report presents guidelines for human factors inputs to the design of synthetic training systems, primarily in the area of operations with special attention to flight simulation, and is addressed to those persons having responsibility for human factors inputs during conception and development of the design of training devices. It outlines a chronological methodology for simulator deverlopment in view of purposes, tasks, and equipment; it discusses human factors concepts and data relevant to the design process; and it details the implementation of the method using the concrete example of a complex shore-based team trainer (Early Attack Warning System Trainer).

   Key concepts set forth in the introduction are:
   (1) The overriding consideration in training system design is the transfer of training from the simulator to the real-world environment;

little training in the principles of learning;
(4) Increasing dissimilarity of new training devices to actual equipment;
(5) Instructors' fear of negative training on an unrealistic-seeming device.

One prominent symptom of user neglect of Research and Development information is that specifications writing for new devices relies chiefly on old models. Also, "all too often in the device specification process, too little attention is given to the particular and specific training tasks and training objectives that the device is to be used to train."

1. Author: Semple, Clarence A.

2. Title: Fidelity: What We Know and Who Should Know It

3. Source: U.S. Army Research Institute for the Behavioral and Social Sciences Technical Report 547, November 1981: Research Issues in the Determination of Simulator Fidelity: Proceedings of the ARI Sponsored Workshop, 23-24 July 1981

4. Topic Keywords: Training Device User ; Fidelity of Simulation ; Negative Transfer .

5. Short Summary: Problems in user acceptance of deliberately lowered fidelity in training devices are discussed. It is recommended those in the RD community consider how to educate users to accept arguments in favor of lowered fidelity.

6. Devices: None discussed

7. Institutions:

a. Sponsor: U.S. A.R.I. for the Behavioral and Social Sciences, 5001 Eisenhower Avenue, Alexandria, VA 22333

b. Performing Organization:
Canyon Research Group, Inc. 741 Lakefield Road, Suite B, Westlake Village, CA 91361

8. Type of Article: Theoretical

9. Abstract: This brief paper deals chiefly with problems in user acceptance of deliberately lowered fidelity in training simulators. Research has found it cost-effective to reduce fidelity in some instances; however, understanding among users of these findings is very limited.

"Users" are identified as "those involved in writing device specifications, developing the courses in which various training devices will be used, the instructors who implement the instruction using the device, and the students who are being trained." The following obstacles to user acceptance of research findings on fidelity, training, and device design are cited:

(1) Lack of technical information on the part of user;
(2) Turnover and reassignment of (especially military) personnel, preventing key decision-makers from reaching the top of their learning curves in the field;
(3) Inadequacy and lack of structure in training users in device utilization; especially, instructors have

The summary of studies on fidelity covers the following topics: visual system fidelity, flight characteristics fidelity, playform motion systems, force cuing, and visual-motion interaction. Important points under these topics are:

(1) While visual systems in simulated flight training appear to be a must, available scientific and operational information comes up short on specific guidance for optimizing visual systems.
(2) The pursuit of very high flight characteristics fidelity may be excessive; however, again there is a lack of systematic scientific information in this area.
(3) Research on the training effectiveness of platform motion cuing is inconclusive.
(4) Force cuing features, e.g., G-seats, are new, and research on their training effectiveness is as yet inadequate.
(5) The lack of synchronization of visual and motion cues due to limitations of simulation equipment can seriously impair training; little empirical data exist on tolerable limits or desirable minimums for asynchrony among visual, motion, and cockpit display cues.

The summary of studies on instructional support features covers the following topics: the instruct function, the monitoring and evaluation of performance, the control and individualization of training, the controller function, instructor/operator console design and location, and instructor/operator training.

The summary of studies on utilization of aircrew training devices covers the following topics: complexity of skill learning, structure of device training, instructors, attitudes, assessment of training effectiveness, and maintaining device effectiveness.

The summary of studies of life cycle cost and worth of ownership covers the following topics: cost model development, cost model uses, cost model procedures, and worth of ownership assessment.

Future research plans are also outlined in this report. Reference is made to an abstract bibliography, and an index is provided for the STRES technical reports on fidelity, instructional features, utilization, and cost/worth.

(f) Can vary the difficulty level
(g) Can provide and overview

Psychological realism, as distinct from physical realism, should be emphasized. Psychologically unimportant details of a task or environment can be left out of simulation for more effective learning.

Despite the demonstrated effectiveness of simulation, this problem remains: "No predictive body of knowledge is available which will ensure the adequate design of simulations for effective training. It does not appear that rigorous scientific methods will be applied to isolate and test possible principles." Instead of a systematic approach to isolate principles, the case study approach is recommended: "...we have performed enough persuasive research through simulation. It appears...that thorough case studies can provide a way in which information can be usefully provided."

1. Author: Valverde, Horace H.

2. Title: A Review of Flight Simulator Transfer of Training Studies

3. Source: Human Factors , 1973, 15(6), 510-523

4. Topic Keywords: Flight Simulation ; Transfer of Training ; Platform Motion .

5. Short Summary: A review of approximately 29 empirical and 5 theoretical studies in flight simulator effectiveness as measured by Transfer of Training is presented. The review points out disparities in findings and concludes by identifying the chief confounding variables: criteria measures, matching of subjects, instructors, and instructional sequence.

6. Devices:

a. Navy SNJ Operational Flight Trainer

b. SNJ Cycloramic Link Trainer

c. P-1 (SNJ) Link Trainer

d. AN-T-18 Link Trainer

e. 1-CA-2 SNJ Link Trainer

f. C-11 Link Trainer

g. B-47 Link Simulator

7. Institutions:

a. Sponsor: , Air Force Human Resources Laboratory , Advanced Systems Division, Wright-Patterson AFB, OH 45433

b. Performing Organization: same

8. Type of Article: Review

9. Abstract: This review of transfer-of-training research on the effectiveness of synthetic flight trainers begins with general arguments in favor of the use of simulators in training; summarizes, one-by-one, the methods and findings of approximately 29 empirical studies; and concludes by identifying the chief confounding variables in transfer-of-training experiments.

General arguments in favor of the use of simulators in flight training, as opposed to the use of actual equipment, are: (1) lower equipment costs; (2) ease of introducing malfunctions; and (3) safety.

The transfer-of-training research which is reviewed focusses on procedures and basic instrument trainers during the period 1949-1970 (all but 5 of the studies are prior to 1966). Studies are categorized under three headings: Fixed Wing; Motion; Rotary Wing (the Motion category is actually a sub-category of fixed-wing).

The author observes in conclusion, that "the various studies on transfer of training from the flight simulator to the actual aircraft have sometimes produced contradictory results. The reason for the disparity in findings may have been due to variables which were not assessed in the experiments." Four chief confounding variables are identified:

(a) The criterion measure. Most performance measures are "judgemental"--i.e., subjective, instructor-scored.

(b) Subjects are matched by paper and pencil tests which may be poor indicators of piloting potential.

(c) The impact of instructors on simulated training is virtually immeasurable although suspected to be large.

(d) The instructional sequence varies from study to study; its impact also is virtually immeasurable given present data; a recent study suggests that block simulator instruction is preferable to alternating sequence.

1. Author: Waag, Wayne L.

2. Title: Training Effectiveness of Visual and Motion Simulation

3. Source: AFHRL-TR-79-72, January 1981

4. Topic Keywords: Visual simulation ; Motion simulation ; Flight simulation ; Transfer of training ; Flight training .

5. Short Summary: A review of available studies of transfer of training from visual and motion simulation to aircraft reveals the general effectiveness of simulator training but points to the lack of experimental data which would demonstrate a systematic quantifiable relationship between simulation fidelity and degree of transfer.

6. Devices: Flight Simulators: 1-CA-2-Link; P1; SNJ Link; T-4G; ASPT/T37; 2F87F; 2F103NCLT; ASPT/A-10; FFT; LAS/WAVS; SAAC; CH047FS; UH-1FS; GAT-2

7. Institutions:

a. Sponsor: HQ Air Force Human Resources Laboratory , Brooks Air Force Base, TX 78235

b. Performing Organization: Operations Training Divbision, AFHRL, Williams Air Force Base, AZ 85224

8. Type of Article: Review

9. Abstract: A review of available studies of transfer of training from flight simulators to aircraft reveals the general effectiveness of simulator training but points to the lack of experimental data which would demonstrate a systematic quantifiable relationship between simulation fidelity and degree of transfer. In particular, the literature suggests that the addition of visual system will enhance the training value of a simulator, whereas the addition of a platform motion system will have little effect.

In this review, 28 different studies are cited, over a period from 1949 to 1980, investigating the transfer of simulation flight training to real aircraft. The studies are primarily related to visual flight simulation of as high fidelity as possible; 10 of the studies focussed on the effects of motion simulation. Flight tasks studied comprised landing/takeoff maneuvers, formation flight, acrobatics and air combat, air-to-surface weapons delivery, and rotary wing flight.

The author points out several problem areas in the field of flight simulation experimentation:

(a) The foremost problem is that of the required fidelity of simulation. Noting that many studies show that full fidelity is not requird, the author specified the unanswered issues bearing on the fidelity requirement;

(i) what skills transfer from the simulator to the aircraft?

(ii) what is the minimum necessary degree of physical realism?

(iii) what cost effectiveness model could be used to compare cost of learning particular skills on the simulator versus the aircraft?

(b) Problems of Experimental Design and Measurement exist among various studies:

(i) Variability of Research Objectives

(ii) Variability of Experimental Design and Control

(iii) Dearth of objective measures of proficiency

(iv) Variability in sample size with an unfortunate tendency to smaller simple sizes

(v) Some minimal questions as to what tasks under study are appropriate

(vi) "Generalizability", i.e., that "there exist no quantifiable models of visual and motion simulation which enable testable hypotheses to be generated which might subsequently lead to some generalizable findings.... The research community, in its attempt to provide 'real world' solutions for today's problems, has failed to develop the framework for obtaining data for tomorrow's issues."

Authors' Conclusions: The literature suggests that the addition of a visual system will enhance the training value of the simulator, whereas the addition of a platform motion system will have little effect. However, there are dangers in attempting to draw conclusions from diverse and often unrelated research studies. In many cases, study goals are different, and the experimental data design and measurements are different. Each of these factors will have an effect (usually unknown) on the study outcome.

1. Authors: Wheaton, George R., Rose, Andrew M., Fingerman, Paul W., Korotkin, Arthur L., Holding, Dennis H., & Mirabella, Angelo

2. Title: Evaluation of the Effectiveness of Training Devices: Literature Review and Preliminary Model

3. Source: U.S. Army Research Institute for the Behavioral and Social Sciences Research Memorandum 76-6, April 1976

4. Topic Keywords: Transfer of Training; Task Analysis; Fidelity of Simulation ; Predictive Model; Training Effectiveness

5. Short Summary: A literature review and discussion of theoretical issues in simulation provides the basis for a preliminary model to predict training effectiveness of devices.

6. Devices: None discussed

7. Institutions:

a. Sponsor: U.S. Army Research Institute for the Behavioral and Social Sciences, Alexandria, VA

b. Performing Organization: same

8. Type of Article: Review/Theoretical

9. Abstract: The technological capacity for building training devices has "far outstripped knowledge about how to design them." The kind of model or conceptual framework required to provide systematic guidelines by which to predict training device effectiveness is lacking. This report is the first in a series describing research aimed at developing and validating a method for predicting training device effectiveness. The report culminates in the presentation of a preliminary model for predicting transfer of training, considered one of the most important, if not the most important, indicators of training effectiveness.

The report is divided into four main sections:
(1) Discusses the results of a literature survey;
(2) Outlines major psychological theories of Transfer of Training;
(3) Summarizes the empirical literature on learning and transfer;
(4) Describes the predictive model.

The first section, in reviewing the available literature,

describes a number of models which are seen to fall under two general headings: task analytic, which focus on learning acquisition rather than transfer, providing prescription rather than prediction; micro-analytic, which focus on comparing specific stimuli and responses, providing either prescription or prediction. The review concludes that no existing models are entirely adequate for prediction.

The second section discusses theoretical positions and issues, specifically similarity theories, mediation theories, the nature of negative transfer, fidelity, and the roles of amount and stage of training in transfer. The similarity theory of transfer appears stronger, but "... it must be recognized that current similarity models seem incapable of accommodating all of the gradients of similarity which are possible... These similarity relations by no means exhaust the list of relevant and powerful variables. Similarity may be a necessary condition for transfer to occur, but it surely is not sufficient....."

The third section summarizes 65 studies in the empirical literature. It begins by identifying and listing the substantive variables, indexed to relevant documents. The variables are classified under three main headings:

(1) "Training" variables, related to the efficiency with which any task could be trained; e.g., amount of practice, knowledge of results, etc.;

(2) "Device" variables, related to the appropriateness of the device to the task to be learned, e.g., fidelity;

(3) "Task" variables, related to the task itself, e.g., difficulty, duration, etc.

The section goes on to discuss briefly each of the variables in turn. It is noted that the fidelity variables have drawn the most attention in research: "Fidelity has been the cornerstone of several device effectiveness models and the basis of most transfer of training theories." The question is considered, of "why the data are so unconvincing in support of fidelity as a direct predictor of training effeciveness," and it is observed that the effects of fidelity on transfer are large: however, these effects are modified... by other considerations," such as task difficulty, amount of practice, etc. This section concludes with a rationale for the synthesis of general training principles, and a list of principles inferred from the literature is provided.

The final section of the paper describes the preliminary model which attempts to generalize and integrate the concepts introduced earlier in the paper. This is done with

a recognition that "... the literature consists mostly of studies with such different approaches, measures, controls, and variables that it is impossible to reconcile, let alone assimilate, all of their findings... there is little which can be systematized into coherent principles or laws."

The tentative model which emerges is "basically a training content by training process model." It organizes content by task description and relevant behavioral categories; it organizes process by "appropriateness" and "efficiency", and finally by their product, "effectiveness".

1. Author: Whiteside, George A.

2. Title: Aircraft Simulator Data Requirements Study: Executive Summary

3. Source: Final Report, ASD-TR-77-25 Vol. I, January 1977

4. Topic Keywords: Flight Simulation ; Computer-Aided Design .

5. Short Summary: A survey of flight simulator manufacturers, simulator acquisition activities, and aircraft manufacturers yields criteria of a General Requirement for supplying data for simulator development. Such a requirement would constitute an up-to-date standard for specifying the data needed by simulator manufactures, including makers of digital computer-driven flight simulators.

6. Devices: None discussed

7. Institutions:

a. Sponsor: Aeronautical Systems Division, Wright-Patterson AFB, OH 45433

b. Performing Organization: Systems Research Laboratories, Inc., 2800 Indian Ripple Road, Dayton, OH 45440

8. Type of Article: Conceptual/Methodological

9. Abstract: Impediments to the flow of data on new aircraft to simulator manufacturers, and suggestions for overcoming them, constitute the subject matter of this report. A survey of flight simulator manufacturers, simulator acquisition activities, and aircraft manufacturers was performed to determine a General Requirement for supplying the necessary data for simulator development on a schedule such that "the simulator can be on-site, ready for training before the first production aircraft is delivered to the operating command."

Discussion of the survey touches on the following topics and problems in the acquisition of data for simulation: acceptance test procedure; malfunction and abnormal operations; barriers to communication between simulator manufacturer and aircraft design engineers; timing of physical data, aerodynamic data estimate, system data estimates, "hot bench" tests, and dynamic tests; intelligence data; tactical program tapes and duplication

of aircraft central computers; enforcement of the data-acquisition schedule; procurement of crew station parts from the aircraft manufacturer; project pilots and project crew members; and role of instructor pilots.

A number of specific recommendations are made to facilitate the supplying of useable data to the simulator manufacturer. The primary recommendations are, that the initial contract for aircraft development should require delivery of the data needed to develop a full mission simulator, and that the activity should follow up on these requirements to ensure a timely delivery of accurate information. The Air Force Flight Test Center must also be tasked to provide handling qualities and performance parameters to the simulator manufacturer as early as possible in the test program; the AFFTC should also assign a qualified test pilot current in the aircraft, and a flight test engineer to assist in the development of the simulator.

1. Authors: Woomer, C. W., & Williams, R. L.

2. Title: Environmental Requirements for Simulated Helicopter/VTOL Operations from Small Ships and Carriers

3. Source: Technical Memo, Naval Air Test Center TM-78-2RW, April 1978

4. Topic Keywords: Rotary Wing Flight Simulation ; Helicopter Simulation Training ; Weapon System Trainer ; Shipboard Environment ; Training Effectiveness; Vertical Take-Off Landing Operations Training ; Visual Landing Aids .

5. Short Summary: The simulation of helicopter flight operation via high-fidelity state-of-the-art devices improve the safety and economics of training.

6. Devices: 2F106 SH-2F Weapons System Trainer

7. Institutions:

a. Sponsor: Naval Air Systems Command, Department of the Navy, Washington, DC 20361

b. Performing Organization: Rotary Wing Aircraft Test Directorate, Naval Air Test Center, Patuxent River, MD 20670

8. Type of Article: Conceptual/Review

9. Abstract: Helicopter/VTOL operations from ships have characteristics which differ greatly from those of fixed-wing flying tasks and appear to demand a high degree of realism in training simulation. This report discusses the demands that this unique flight environment makes of training simulators, and describes developing state-of-the-art technology for meeting these demands, particularly as exemplified by Device 2F106, the SH-2F Weapons System Trainer (WST).

The demands of simulating helicopter/VTOL operations from ships are:

(a) Low altitude, low airspeed flight regime is particularly limited by visual system lag time. Maximum tolerances are a few hundred milliseconds;
(b) Response in all visual axes is critical; yaw response is much more demanding than in a fixed wing aircraft;
(c) Field-of-view in simulation is probably more demanding than in fixed-wing aircraft simulation;

(d) Occultation, as of the sea horizon by a ships's super- structure, is mandated, as horizon image when in view appears to take precedence over other scene content;
(e) "A full 6 degrees of freedom motion system appears to be... a necessity to VTOL trainers.... Significantly improved pilot performance has been noted with the inclusion of the system.";
(f) Ship motion models are required;
(7) Turbulence, relative wind, ground aerodynamic effect, and sound, are all highly important workload and/or cueing elements for the helicopter pilot.

State-of-the-art calligraphic visual systems provide highly promising visual simulation capabilities, including occultation, and dynamic focussing and defocussing of scene elements, as new capabilities.

Another technological improvement is in the reduction of lag time in the visual system. In VITAL IV image generation, lag has been demonstrated to be less than 50 milliseconds.

The authors conclude by reiterating the need for high fidelity in training simulation in this application, and by emphasizing the importance of new technologies in meeting this need.

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